# FACTOR IX/FACTOR Ixa ACTIVATING ANTIBODIES AND ANTIBODY DERIVATIVES

The present invention relates to actor IX/factor IXa-antibodies and antibody derivatives.

Blood clots (thrombi) are formed by a series of zymogen activations referred to as the coagulation cascade. In the course of this enzymatic cascade, the activated form of each of such zymogens (referred to as factors) catalyzes the activation of the next one. Thrombi are deposits of blood components on the surface of a blood vessel wall and mainly consist of aggregated blood platelets and insoluble, cross-linked fibrin. Fibrin formation is effected by means of thrombin by limited proteolysis of fibrinogen. Thrombin is the final product of the coagulation cascade, (K.G. Mann, Blood, 1990, Vol. 76, pp.1-16).

Activation of factor X by the complex of activated factor IX (FIXa) and activated factor VIII (FVIIIa) is a key step in coagulation. The absence of the components of this complex or a disturbance of their function is associated with the blood coagulation disorder called hemophilia (J.E. Sadler & E.W. Davie: Hemophilia A, Hemophilia B and von Willebrand's disease, in G. Stamatoyannopoulos et al. (Eds.): The molecular basis of blood diseases. W.B. Saunders Co., Philadelphia, 1987, pp. 576-602). Hemophilia A denotes a (functional) absence of factor VIII activity, while Hemophilia B is characterized by the absence of factor IX activity. At present, treatment of Hemophilia A is effected via a substitution therapy by administering factor VIII concentrates. However, approximately 20-30% of Hemophilia A patients develop factor VIII inhibitors (i.e. antibodies against factor VIII), whereby the effect of administered factor VIII preparations is inhibited. Treatment of factor VIII inhibitor patients

is very difficult and involves risks, and so far there exist only a limited number of treatments for these patients.

In the case of patients having a low FVIII inhibitor level, it is possible, though expensive, to administer high doses of factor VIII to such patients and thus to neutralize the antibodies against factor VIII. The amount of factor VIII beyond that needed to neutralize the inhibitor antibodies then has hemostatic action. In many cases, desensitization can be effected, whereupon it is then possible again to apply standard factor VIII treatments. Such high dose factor VIII treatments require, however, large amounts of factor VIII, are time-consuming and may involve severe anaphylactic side reactions. Alternatively, the treatment may be carried out with porcine factor VIII molecules.

A further high-cost method involves removing factor VIII inhibitors through extra corporeal immunoadsorption on lectins which bind to immunoglobulins (protein A, protein G) or to immobilized factor VIII. Since the patient must be connected to an apheresis machine during this treatment, the treatment also constitutes a great burden on the patient. It is also not possible to treat an acute hemorrhage in this way.

At present, the therapy of choice is to administer activated prothrombin complex concentrates (APCC), such as FEIBA® and AUTOPLEX®, which are suitable for the treatment of acute hemorrhages even in patients having a high inhibitor titer (DE 31 27 318).

In the intravascular system of blood coagulation, the last step is the activation of factor X. This reaction is stimulated by the binding of factor VIIIa to factor IXa and the formation of a "tenase"-complex consisting of the factors IXa, VIIIa, X and phospholipid. Without the binding of FVIIIa, FIXa

exhibits no or only a very slight enzymatic activity relative to FX.

Over the last several years, a number of possible binding sites for factor VIIIa to factor IXa have been characterized, and it has been shown that antibodies or peptides which bind to these regions inhibit the activity of FIXa (Fay et al., J. Biol. Chem., 1994, Vol.269, pp.20522-20527, Lenting et al., J. Biol. Chem., 1996, Vol. 271, pp. 1935-1940, Jorquera et al., Circulation, 1992, Vol. 86, Abstract 2725). The inhibition of coagulation factors, such as factor IX, has also been achieved through the use of monoclonal antibodies with the aim of preventing thrombosis formation (WO 97/26010).

The opposite effect, i.e. an increase in the factor IXa mediated activation of factor X, has been described by Liles D.K. et al., (Blood, 1997, Vol. 90, suppl. 1, 2054) through the binding of a factor VIII peptide (amino acids 698-712) to factor IX. Yet, this effect only occurs in the absence of factor VIIIa, while in the presence of factor VIIIa the factor IXa/factor VIIIa-mediated cleavage of factor X is inhibited by this peptide.

**SUMMARY OF THE INVENTION**

With a view to the possible risks and side effects which may occur in the treatment of hemophilia patients, there is a need for a therapy which allows for the effective treatment of FVIII inhibitor patients. Therefore, it is an object of the present invention to provide a preparation for the treatment of blood coagulation disorders which has particular advantages for factor VIII inhibitor patients.

According to the present invention, this object is achieved through the use of antibodies or antibody derivatives against factor IX/factor IXa which have factor VIIIa-cofactor activity or factor IXa-activating

activity and lead to an increase in the procoagulant activity of factor IXa. Surprisingly, the action of these inventive factor IX/factor IXa-activating antibodies and antibody derivatives is not negatively affected by the presence of inhibitors, such as inhibitors against factor VIII/factor VIIIa, but instead the procoagulant activity of factor IXa in this case also is increased.

A further advantage of this invention is that the administration of the preparation according to the invention allows for rapid blood coagulation even in the absence of factor VIII or factor VIIIa, even in the case of FVIII inhibitor patients. Surprisingly, these agents are also effective in the presence of factor VIIIa.

The antibodies and antibody derivatives according to the present invention thus have a FVIII-cofactor-like activity which, in a FVIII assay (e.g. a COATEST® assay or Immunochrom test) after 2 hours of incubation exhibits a ratio of background (basic noise) to measured value of at least 3. Calculation of this ratio may, e.g., be effected according to the following scheme:

$$\frac{\text{Antibody measurement (OD 405) – blank value from reagent}}{\text{Mouse-IgG-measurement (OD 405) – blank value from reagent}} \geq 3$$

after two hours of incubation.

The antibodies according to the invention preferably have an in vivo half life of at least 5 days, more preferably at least 10 days, though it is more preferred to have a half life of at least 20 days.

A further aspect of this invention is a preparation comprising antibodies and/or antibody derivatives against factor IX/factor IXa and a pharmaceutically acceptable carrier substance. Furthermore, the preparation according to the invention may additionally comprise factor IX and/or factor IXa.

A further aspect of the invention is the use of the antibodies or antibody derivatives to increase the amidolytic activity of factor Ixa.

Fig. 1 shows the results of a screening of supernatants from hybridoma cell cultures for FVIII-like activity. Pre-selected clones from fusion experiments, #193, #195 and #196, were tested in a chromogenic assay.

Fig. 2 shows the results of screening for IgG-mediated factor VIII-like activity in supernatants of a hybridoma cell culture of a master plate.

Fig. 3 shows the subcloning of clone 193/C0, namely the results of the first cloning round.

Fig. 4 shows a comparison of the chromogenic FVIII-like activity and factor IX-ELISA-reactivity of hybridoma cultures derived from the starting clone 193/C0.

Fig. 5 shows the results of the measurement of the chromogenic activity of some master clones and sub-clones.

Fig. 6A shows the FVIII-like activity of the anti-FIX/FIXa-antibodies 193/AD3 and 196/AF2 compared to human FVIII, TBS buffer and cell culture medium. After a lag phase, both antibodies gave rise to chromogenic substrate cleavage, as judged by the increasing optical density.

Fig. 6B shows a comparison of the chromogenic activity of factor VIII, 196/AF1, 198/AC1/1 and mouse-IgG.

Fig. 7A shows a comparison of the kinetics of Factor Xa generation by Factor VIII and 196/AF2 with and without the addition of a Factor Xa specific inhibitor.

Fig. 7B shows a comparison of the kinetics of the Factor Xa generation by Factor VIII, mouse-IgG and anti-factor IX/IXa-antibody 198/AM1 with and without the addition of a factor Xa-specific inhibitor, Pefabloc Xa®.

Fig. 8A shows a measurement of the dependence of the factor VIII-like activity of purified anti-factor IX/IXa-antibody 198/AC1/1 in the presence and absence of phospholipids, FIXa/FX and calcium ions.

Fig. 8B shows a measurement of the dependence of FXa generation by anti-FIXa-antibody 196/AF1 in the presence of phospholipids, $Ca^{2+}$ in FIXa/FX.

Fig. 8C shows the generation of FXa by unspecific mouse IgG antibody.

Fig. 9 is a graphical representation of the coagulation times of Factor VIII-deficient plasma in an APTT assay by using various concentrations of anti-factor IX/IXa-antibody 193/AD3.

Fig. 10A shows that in the presence of Factor IXa, antibody 193/AD3 leads to a reduction in the coagulation time of factor VIII-deficient plasma.

Fig. 10B shows a dose-dependent reduction of the clotting time by antibody 193/AD3 in the presence of factor IXa- and factor VIII-inhibitors.

Fig. 11 shows the chromogenic activity of antibodies 198/A1, 198/B1 and 198/AP1 in the presence and absence of human FIXaβ.

Fig. 12 shows the primer sequences for the amplification of the genes of the variable heavy chain of mouse antibody.

Fig. 13 shows the primer sequences for the amplification of the genes of the variable light (kappa) chain of the mouse antibody.

Fig. 14 shows the DNA and derived protein sequence of the scFv from hybridoma cell line 193/AD3 (SEQ.ID.NOs. 81 and 82).

Fig. 15 shows the DNA and derived protein sequence of the scFv from hybridoma cell line 193/K2 (SEQ.ID.NOs. 83 and 84).

Fig. 16 shows the DNA and derived protein sequence of the scFv from hybridoma cell line 198/AB2 (subclone of 198/B1) (SEQ.ID.NOs. 85 and 86).

Fig. 17 shows the DNA and deduced protein sequence of scFv derived from the cell line 198/A1 (SEQ.ID.NOs. 87 and 88).

Fig. 18 demonstrates the chromogenic FVIII-like activity of peptide A1/3 in the presence of 2.9nM human FIXa. The scrambled version of peptide A1/3, peptide A1/5 does not give rise to any FXa generation.

Fig. 19 demonstrates the dependence of the chromogenic FVIII-like activity of peptide A1/3 on the presence of human FIXa. In the absence of human FIXa, peptide A1/3 does not give rise to any FXa generation. The buffer control, plain imidazole buffer is designated IZ.

Fig. 20 shows that the chirality of Arg-residues does not play a significant role for the chromogenic activity of peptides A1/3-rd and A1/3-Rd-srmb.

Fig. 21 shows that the addition of 2.4µM peptide B1/7 to the reaction mixture led to a measureable generation of Fxa.

Fig. 22 shows that the addition of a FX-specific inhibitor results in a significant reduction in the reaction. If there was no FIXa and FX is added to the reaction mixture, no FXa was synthesized.

Fig. 23 shows vector pBax-IgG1.

Fig. 24 shows the increase of the amidolytic activity of FIXa in the presence of antibody 198/B1 (Fig. 24A) and IgM antibody 198/AF1 (Fig. 24B).

Fig. 25 demonstrates the chromogenic FVIII-like activity of the antibody 198/A1 Fab fragment in the presence of 2.8nM human FIXa. As a positive control the intact antibody 198/A1 was used as well as 7.5pM FVIII. The buffer control (IZ) was used as a negative control.

Fig. 26 shows the nucleotide and amino acid sequence of the 198AB2 scFv-alkaline phosphatase fusion

protein (ORF of the expression vector pDAP2-198AB2#100, (SEQ.ID.NOs. 89 and 90).

The genes for the VL and the VH domains of antibody 198/AB2 (198/AB2 is an identical subclone of 198/B1) were derived from the corresponding hybridoma cells as described in example 10. The PCR product of the VH-gene was digested SfiI - AscI and the PCR-product of the VL-gene was digested AscI and NotI. VH and VL genes were linked via the AscI site and inserted into SfiI - NotI digested vector pDAP2 (Kerschbaumer R.J. et al, Immunotechnology 2, 145-150, 1996; GeneBank accession No.:U35316). PelB leader: leader sequence of *Erwinia carotovora* Pectate Lyase B, His tag, Histidinee tag for metal ion chromatography.

Fig. 27 demonstrates the chromogenic FVIII-like activity of two antibody 198/B1 (subclone AB2) scFv fragment-alkaline phosphatase fusion proteins (198AB2#1 and 198AB2#100) in the presence of 2.3nM human FIXa. As a positive control 7.5pM FVIII was used.

Fig. 28 shows the amino acid and nucleotide sequence of pZip198AB2#102 (SEQ.ID.NOs. 91 and 92).

Fig. 29 shows the nucleotide and amino acid sequence of the mAB#8860 scFv-alkaline phosphatase fusion protein (vector pDAP2-8860scFv#11, (SEQ.ID.NOs. 93 and 94). The genes for the VL and the VH domains of antibody #8860 were derived from the corresponding hybridoma cells as described in example 10. The PCR product of the VH-gene was digested SfiI - AscI and the PCR-product of the VL-gene was digested AscI and NotI. VH and VL genes were linked via the AscI site and inserted into SfiI - NotI digested vector pDAP2 (Kerschbaumer R.J. et al, Immunotechnology 2, 145-150, 1996; GeneBank accession No.:U35316).

Fig. 30 shows the nucleotide and amino acid sequence of the mAB #8860 scFv-leucine zipper fusion

protein (miniantibody; vector p8860-Zip#1.2, (SEQ.ID.NOs. 95 and 96). The gene of the scFv fragment was derived from mAB #8860 and was swapped from vector pDAP2-8860scFv#11 into SfiI-NotI digested plasmid pZip1 (Kerschbaumer R.J. et al., Analytical Biochemistry 249, 219-227, 1997; GeneBank accession No.: U94951).

Fig. 31 demonstrates the chromogenic FVIII-like activity of the 198/B1 (subclone AB2) miniantibody 198AB-Zip#102 in the presence of 2.3nM human FIXa. As a positive control 4.8pM FVIII was used whereas a unrelated miniantibody (8860-Zip#1.2) and plain reaction buffer (IZ) served as negative controls.

Fig. 32 shows a schematic representation of the plasmid pMycHis6.

Fig. 33 shows the nucleotide and amino acid sequence of the part of the plasmid pMycHis6 differing from vector pCOCK (SEQ.ID.NOs. 97 and 98). Vector pMycHis6 was constructed by cleaving vector pCOCK (Engelhardt et al., 1994, Biotechniques, 17:44-46) with NotI and EcoRI and insertion of the oligonucleotides: mychis6-co: 5'ggccgcagaacaaaaactcatctcagaagaggatct gaatggggcggcacatcaccatcaccatcactaataag 3' (SEQ ID.No. 79) and mycchis-ic: 5'aattcttattagtgatggtgatggtgatgtgccgccccattcagatcctcttct gagatgagtttttgttctgc (SEQ.ID.No. 80).

Fig. 34 shows the nucleotide and amino acid sequence of 198AB2 scFv (linked to the c-myc-tag and the His6- tag): ORF of the expression vector pMycHis6-198AB2#102. Vector pMycHis6 was constructed by cleaving vector pCOCK (Engelhardt O. et al, BioTechniques 17, 44-46, 1994) NotI - EcoRI and inserting the following annealed oligonucleotides:
(5'-GGCCGCAGAACAAAAACTCATCTCAGAAGAGGATCTGAATGGG GCGGCACATCACCATCACCATCACTAATAAG - 3' (SEQ.ID.No. 103) and
5'- TTATTAGTGATGGTGATGGT GATGTGCCGCCCCATTCAGATCCTCTTCTGAGATGAGTTTTTGTTCTGC-

3' (SEQ.ID.NO. 104)). The resultant vector, named pMycHis6, was cleaved SfiI - NotI and the gene of scFv 198AB2 was swapped into this vector from vector pDAP2-198AB2#100.

Fig. 35 shows the nucleotide and amino acid sequence of the mAB #8860 scFv linked to the c-myc-tag and the His6- tag (vector p8860-M/H#4c, SEQ.ID.NOs. 101 and 102). Plasmid pMycHis6 was cleaved with SfiI and NotI and the DNA sequence coding for the scFv 8860#11 protein was inserted from pDAP2-8860scFv#11 (see Fig.29) yielding plasmid p8860-M/H#4c.

Fig. 36 demonstrates the chromogenic FVIII-like activity of the 198/B1 (subclone AB2) scFv fragment (MycHis-198AB2#102) in the presence of 2.3nM human FIXa. As a positive control 4.3pM FVIII was used whereas a unrelated scFv (8860-M/H#4c) and plain reaction buffer (IZ) served as negative controls.

**Antibodies and Antibody Derivatives**

The present invention also comprises the nucleic acids encoding the inventive antibodies and antibody derivatives, expression vectors, hybridoma cell lines, and methods for producing the same.

Antibodies are immunoglobulin molecules having a specific amino acid sequence which only bind to antigens that induce their synthesis (or its immunogen, respectively) or to antigens (or immunogens) which are very similar to the former. Each immunoglobulin molecule consists of two types of polypeptide chains. Each molecule consists of large, identical heavy chains (H chains) and two light, also identical chains (L chains). The polypeptides are connected by disulfide bridges and non-covalent bonds. In vivo, the heavy and light chains are formed on different ribosomes, assembled in the cell, and secreted as intact immunoglobulins (Roitt I. et al., in: Immunology, second ed., 1989).

The inventive antibodies and antibody derivatives and organic compounds derived there from comprise human and animal monoclonal antibodies or fragments thereof, single chain antibodies and fragments thereof and miniantibodies, bispecific antibodies, diabodies, triabodies, or di-, oligo- or multimers thereof. Also included are peptidomimetics or peptides derived from the antibodies according to the invention, e.g. they comprise one or several CDR regions, preferably the CDR3 region.

Further included are human monoclonal antibodies and peptide sequences which, based on a structure activity connection, are produced through an artificial modeling process (Greer J. et al., J. Med. Chem., 1994, Vol. 37, pp. 1035-1054).

The term factor IX/IXa activating antibodies and antibody derivatives may also include proteins produced by expression of an altered, immunoglobulin-encoding region in a host cell, e.g. "technically modified antibodies" such as synthetic antibodies, chimeric or humanized antibodies, or mixtures thereof, or antibody fragments which partially or completely lack the constant region, e.g. Fv, Fab, Fab' or $F(ab)'_2$ etc. In these technically modified antibodies, e.g., a part or parts of the light and/or heavy chain may be substituted. Such molecules may, e.g., comprise antibodies consisting of a humanized heavy chain and an unmodified light chain (or chimeric light chain), or vice versa. The terms Fv, Fc, Fd, Fab, Fab' or $F(ab)_2$ are used as described in the prior art (Harlow E. and Lane D., in "Antibodies, A Laboratory Manual", Cold Spring Harbor Laboratory, 1988).

The present invention also comprises the use of Fab fragments or $F(ab)_2$ fragments which are derived from monoclonal antibodies (mAb), which are directed against factor IX/factor IXa and cause an increase of the procoagulant activity of factor IXa.

Preferably, the heterologous framework regions and constant regions are selected from the human immunoglobulin classes and isotypes, such as IgG (subtypes 1 to 4), IgM, IgA and IgE. In the course of the immune response, a class switch of the immunoglobulins may occur, e.g. a switch from IgM to IgG; therein, the constant regions are exchanged, e.g. from $\mu$ to $\gamma$. A class switch may also be caused in a directed manner by means of genetic engineering methods ("directed class switch recombination"), as is known from the prior art (Esser C. and Radbruch A., Annu. Rev. Immunol., 1990, Vol. 8, pp. 717-735). However, the antibodies and antibody derivatives according to the present invention need not comprise exclusively human sequences of the immunoglobulin proteins.

In one particular embodiment, a humanized antibody comprises complement determining regions (CDRs) from murine monoclonal antibodies which are inserted in the framework regions of selected human antibody sequences. However, human CDR regions can also be used. Preferably, the variable regions in the human light and heavy chains are technically altered by one or more CDR exchanges. It is also possible to use all six CDRs or varying combinations of less than six CDRs.

The humanized antibody according to the present invention preferably has the structure of a human antibody or of a fragment thereof and comprises the combination of characteristics necessary for a therapeutic application, e.g., the treatment of coagulation disorders in patients, preferably factor VIII inhibitor patients.

A chimeric antibody differs from a humanized antibody in that it comprises the entire variable regions including the framework regions of the heavy and light chains of non-human origin in combination with the constant regions of both chains from human immuno-

globulin. A chimeric antibody consisting of murine and human sequences may, for example, be produced. According to the present invention, the antibodies and antibody derivatives may also be single chain antibodies or miniantibodies (scFv fragments, which, e.g., are linked to proline-rich sequences and oligomerisation domains, e.g. Pluckthun A. and Pack P., Immunotechnology, 1997, Vol. 3, pp. 83-105) or single chain Fv (sFv) which incorporate the entire antibody binding region in one single polypeptide chain. For instance, single chain antibodies may be formed by linking the V-genes to an oligonucleotide which has been constructed as a linker sequence and connects the C terminus of the first V region with the N terminus of the second V region, e.g. in the arrangement VH-Linker-VL or VL-Linker-$V_H$; both, $V_H$ and $V_L$ thus may represent the N-terminal domain (Huston JS et al., Int. Rev. Immunol., 1993, Vol. 10, pp. 195-217; Raag R. and Whitlow M., FASEB J., 1995, Vol. 9, pp. 73-80). The protein which can be used as linker sequence may, e.g., have a length of up to 150 Å, preferably up to 80 Å, and more preferably up to 40 Å. Linker sequences containing glycine and serine are particularly preferred for their flexibility, or glutamine and lysine, respectively, for their solubility. The choice of the amino acid is effected according to the criteria of immunogenicity and stability, also depending on whether or not these single chain antibodies are to be suitable for physiological or industrial applications (e.g. immunoaffinity chromatography). The single chain antibodies may also be present as aggregates, e.g. as trimers, oligomers or multimers. The linker sequence may, however, also be missing, and the connection of the $V_H$ and $V_L$ chains may occur directly.

Bispecific antibodies are macromolecular, heterobifunctional cross-linkers having two different binding specificities within one single molecule. In

this group belong, e.g., bispecific (bs) IgGs, bs IgM-IgAs, bs IgA-dimers, bs $(Fab')_3$, bs$(scFv)_2$, diabodies, and bs bis Fab Fc (Cao Y. and Suresh M.R., Bioconjugate Chem., 1998, Vol. 9, pp. 635-644).

By peptidomimetics, protein components of low molecular weight are understood which imitate the structure of a natural peptide component, or of templates which induce a specific structure formation in an adjacent peptide sequence (Kemp DS, Trends Biotechnol., 1990, pp. 249-255). The peptidomimetics may, e.g., be derived from the CDR3 domains. Methodical mutational analysis of a given peptide sequence, i.e. by alanine or glutamic acid scanning mutational analysis, allows for the identification of peptide residues critical for procoagulant activity. Another possibility to improve the activity of a certain peptide sequence is the use of peptide libraries combined with high throughput screening.

The term antibodies and antibody derivatives may also comprise agents which have been obtained by analysis of data relating to structure-activity relationships. These compounds may also be used as peptidomimetics (Grassy G. et al., Nature Biotechnol., 1998, Vol. 16, pp. 748-752; Greer J. et al., J. Med. Chem., 1994, Vol. 37, pp. 1035-1054).

Examples of hybridoma cells expressing the antibodies or antibody derivatives according to the invention were deposited on 9 September 1999 under the numbers 99090924 (#198/A1), 99090925 (#198/B1) and 99090926 (#198/BB1) and on December 16, 1999 under the numbers 99121614 (#193/A0), 99121615 (#196/C4), 99121616 (#198/D1), 99121617 (198/T2), 99121618 (#198/G2), 99121619 (#198/AC1) and 99121620 (#198/U2) according to the Budapest Treaty.

**Methods of Production**:

The antibodies of the present invention can be prepared by methods known from the prior art, e.g. by

conventional hybridoma techniques, or by means of phage display gene libraries, immunoglobulin chain shuffling or humanizing techniques (Harlow E. and Lane D., in: Antibodies, A Laboratory Manual, Cold Spring Harbor Laboratory, 1988). The production of the inventive antibodies and antibody derivatives may, for instance, be made by conventional hybridoma techniques (Antibodies, A Laboratory Manual, Cold Spring Harbor Laboratory, 1988, Eds. Harlow and Lane, pp. 148-242). According to the present invention, human and also non-human species may be employed therefor, such as cattle, pigs, monkeys, chickens and rodents (mice, rats). Normal, immunocompetent Balb/c mice or FIX-deficient mice may, e.g., be used (factor IX-deficient mice may be obtained from Dr. Darrel Stafford from the University of North Carolina, Chapel Hill). Immunization may, e.g., be effected with factor IX, factor IXa$\alpha$ or completely activated factor IXa$\beta$, or with fragments thereof.

The hybridomas are selected with a view to the fact that the antibodies and antibody derivatives in the supernatants of the hybridoma cells bind to factor IX/factor IXa and cause an increase of the procoagulant activity of factor IXa. The increase in the procoagulant activity may, e.g., be proven by assaying methods as known from the prior art for the measurement of factor VIII-like activity, e.g. chromogenic assays.

Alternatively, the antibodies and antibody derivatives of the invention may also be produced by recombinant production methods. In doing so, the DNA sequence of the antibodies according to the invention can be determined by known techniques, and the entire antibody DNA or parts thereof can be expressed in suitable systems. Recombinant production methods can be used, such as those involving phage display, synthetic and natural libraries, expression of the antibody proteins in known expression systems, or expression in transgenic animals (Jones et al., Nature, 1986, Vol.

321, pp.522-525; Phage Display of Peptides and Proteins, A Laboratory Manual, 1996, Eds. Kay et al., pp. 127-139; US 4,873,316; Vaughan T.J. et al., Nature Biotechnology, 1998, pp. 535-539; Persic L. et al., Gene, 1997, pp. 9-18; Ames R.S. et al., J.Immunol.Methods, 1995, pp. 177-186).

The expression of recombinantly produced antibodies may be effected by means of conventional expression vectors, such as bacterial vectors, such as pBr322 and its derivatives, pSKF or eukaryotic vectors, such as pMSG and SV40 vectors. Those sequences which encode the antibody may be provided with regulatory sequences which regulate the replication, expression and secretion from the host cell. These regulatory sequences comprise promoters, e.g. CMV or SV40, and signal sequences.

The expression vectors may also comprise selection and amplification markers, such as the dihydrofolate reductase gene (DHFR), hygromycin-B- phosphotransferase, thymidine-kinase etc.

The components of the vectors used, such as selection markers, replicons, enhancers etc., may either be commercially obtained or prepared by means of conventional methods. The vectors may be constructed for the expression in various cell cultures, e.g. for mammalian cells such as CHO, COS, fibroblasts, insect cells, yeast or bacteria, such as E. coli. Preferably, those cells are used which allow for an optimal glycosylation of the expressed protein. Particularly preferred is the vector pBax (cf. Fig. 17) which is expressed in CHO cells or in SK-Hep.

The production of Fab fragments or $F(ab)_2$ fragments may be effected according to methods known from the prior art, e.g. by cleaving a mAb with proteolytic enzymes, such as papain and/or pepsin, or by recombinant methods. These Fab and $F(ab)_2$ fragments may also be prepared by means of a phage display gene library (Winter et al., 1994, Ann. Rev. Immunol., 12:433-455).

The antibody derivatives may also be prepared by means of methods known from the prior art, e.g. by molecular modeling, e.g. from Grassy G. et al., Nature Biotechnol., 1998, Vol. 16, pp. 748-752, or Greer J. et al., J. Med. Chem., Vol. 37, pp. 1035-1054, or Rees A. et al., in: "Protein Structure Prediction: A practical approach", ed. Sternberg M.J.E., IRL press, 1996, chapt. 7-10, pp. 141-261.

The purification of the inventive antibodies and antibody derivatives may also be carried out by methods described in the prior art, e.g., by ammonium sulfate precipitation, affinity purification (protein G-Sepharose), ion exchange chromatography, or gel chromatography. The following methods may be used as the test methods to show that the antibodies and antibody derivatives of the present invention bind to factor IX/factor IXa, increase the procoagulant activity of factor IXa or have factor VIII-like activity.: the one step coagulation test (Mikaelsson and Oswaldson, Scand. J. Haematol., Suppl., 33, pp. 79-86, 1984) or the chromogenic tests, such as COATEST VIII:C® (Chromogenix) or Immunochrom (IMMUNO). In principle, all the methods used for determining factor VIII activity may be used. As the control blank value for the measurements, e.g., unspecific mouse-IgG antibody may be used.

The present antibodies and antibody derivatives are suitable for therapeutic use in the treatment of coagulation disorders, e.g. in the case of hemophilia A, for factor VIII inhibitor patients etc. Administration may be effected by any method suitable to effectively administer the therapeutic agent to the patient, e.g. by oral, subcutaneous, intramuscular, intravenous or intranasal administration.

Therapeutic agents according to the invention may be produced as preparations which comprise a sufficient amount of antibodies or of antibody derivatives as the active agent in a pharmaceutically acceptable carrier

substance. These agents may be present either in liquid or in powderized form. Moreover, the preparations according to the invention may also comprise mixtures of different antibodies, the derivatives thereof and/or organic compounds derived therefrom, as well as mixtures consisting of antibodies and factor IX and/or factor IXa. Factor IXa may be present as factor IXaα and/or factor IXaβ. An example of an aqueous carrier substance is, e.g., saline. The solutions are sterile, sterilisation being effected by conventional methods.

The antibodies or antibody derivatives according to the invention may be present in lyophilized form for storage and be suspended in a suitable solvent before administration. This method has proven generally advantageous for conventional immunoglobulins, and known lyophilisation and reconstitution methods may be applied in this case.

Moreover, the antibodies and antibody derivatives according to the invention may also be used for industrial applications, e.g. for the purification of factor IX/factor IXa by means of affinity chromatography, or as a component of detection methods (e.g. ELISA assays), or as an agent for identification of and interaction with functional domains of a target protein.

The present invention will be described in more detail by way of the following examples and drawing figures, to which, however, it shall not be restricted.

**Examples**

**Example 1: Immunization of immunocompetent mice and generation of anti-FIX/IXa antibody secreting hybridoma cells**

Groups of 1-3 normal immunocompetent 5-8 week old Balb/c mice were immunized with 100µg antigen (100µl doses) via the intraperitoneal (i.p.) route. In a typical experiment, mice were inoculated with either recombinant human coagulation factor (F) IX (Benefix$^{TM}$),

human activated FIXaα (Enzyme Research Laboratories, Lot: FIXaα 1190L) or human FIXaβ (Enzyme Research Laboratories, Lot: HFIXAaβ 1332 AL,) adjuvanted with Al(OH)$_3$ or KFA.

Individual mice were boosted at various times with 100µg antigen (100µl doses, i.p) and sacrificed two days later. Spleen cells were removed and fused to P3 X63-Ag8 6.5.3 myeloma cells essentially as described by Lane et al., 1985 (J. Immunol. Methods, Vol. 81, pp. 223-228). Each fusion experiment was individually numbered, i.e. #193, 195, 196 or 198.

Hybridoma cells were grown in 96 well plates on a macrophage feeder layer (app. $10^5$ cells/ml) and selected in HAT-medium (RPMI-1640 medium supplemented with antibiotics, 10% FCS, Na-pyruvate, L-glutamine, 2-mercaptoethanol and HAT (HAT 100x: $1.0x10^{-2}$M hypoxanthine in $H_2O$ (136.1 mg/100ml $H_2O$), $4.0x10^{-5}$M aminopterin in $H_2O$ (1.76 mg/100ml $H_2O$) and $1.6x10^{-3}$M thymidine in $H_2O$ (38.7 mg/100ml $H_2O$). Medium was first changed after 6 days and thereafter twice a week. After 2-3 weeks HAT-medium was changed to HT-medium (RpMI-1640 supplemented with antibiotics, 10%FCS, Na-pyruvate, L-glutamine, 2-mercaptoethanol and HT) and later on (after additional 1-2 weeks) to normal growth medium (RPMI-1640 medium supplemented with 10%FCS, Na-pyruvate, L-glutamine and 2-mercaptoethanol) (see: HYBRIDOMA TECHNIQUES, EMBO, SKMB Course 1980, Basel).

In another set of experiments FIX deficient C57B16 mice (Lin et al., 1997, Blood, 90:3962) were used for immunization and subsequent hybridoma production. Since FIX knockout (k.o.) mice do not express endogenous FIX, the anti (a)-FIX antibody spectrum achievable is supposed to be different compared to normal Balb/c mice (due to lack of tolerance).

**Example 2: Assaying for FVIII-like activity in supernatants of anti-FIX/FIXa antibody secreting hybridoma cells**

In order to assay the FVIII-like activity of anti-FIXa antibodies secreted by hybridoma cells, the commercially available test-kit COATEST VIII:C/4' (Chromogenix) was employed. The assay was done essentially as described by the manufacturer with the following modifications:

To allow high throughput screening, the assay was downscaled to microtiter plate format. Briefly, 25µl aliquots of hybridoma supernatants were transferred to microtiter plate (Costar, #3598) wells and warmed to 37°C. Chromogenic substrate (S-2222), synthetic thrombin inhibitor (I-2581), factor (F) IXa and FX were reconstituted in sterile water and FIXa/FX was mixed with phospholipids according to the supplier's protocol. Per reaction, 50µl of the phospholipid/FIXa/FX solution were combined with 25µl $CaCl_2$ (25mM) and 50µl of the substrate/inhibitor cocktail. To start the reaction, 125µl of the premix were added to the hybridoma supernatant in the microtiter plates and incubated at 37°C. Absorbency at 405nm and 490nm of the samples was read at various times (30min to 12h) against a reagent blank (MLW, cell culture medium instead of hybridoma supernatant) in a Labsystems iEMS Reader MF$^{TM}$ microtiter plate reader. FVIII-like activity of the samples was calculated by comparing the absorbency of the samples against the absorbency of a diluted FVIII reference standard (IMMUNO AG # 5T4AR00) using GENESIS$^{TM}$ software.

The results of a screening for FVIII-like activity in hybridoma cell culture supernatants are shown in Fig. 1. Pre-selected clones derived from fusion experiments #193, #195 and #196 (see above) were examined in a chromogenic FVIII assay as described. Clones 193/M1, 193/N1 and 193/P1 are subclones derived from the master

clone 193/C0 (see below). Master clone 195/10 was derived from fusion experiment #195 and clones 196/A0, 196/B0 and 196/C0 were derived from fusion experiment #196. In a typical screening experiment, approximately 1000 clones (in 96 wells) from a single fusion experiment were pre-screened for FVIII-like activity. Subsequently, selected clones were grown on a larger scale (3-5 ml supernatant) and re-analyzed in a chromogenic assay. As a negative control cell culture medium was assayed on each plate (MLW).

Wells either exhibiting high FVIII-like activity or substantial FVIII-like activity were subjected to subcloning procedures. The selection and subcloning process is exemplified for the screening and subcloning of an IgG producing cell line (i.e. 193/C0) but has been done exactly the same way for an IgM (i.e. 196/C0, see below, Fig. 5) producing clone.

The selection process was done by initially plating all hybridoma cell clones derived from a single fusion experiment on ten 96 well plates thereby creating the so called "master plates". Singular positions (wells) on a master plate usually contained more than one hybridoma cell clone (usually 3 to 15 different clones). Subsequently, the antibody secreted by only several thousand cells was tested. These cells grew under conditions suboptimal for antibody production, which is known to be best in dying cells. So the expected specific anti-FIX antibody concentration in the supernatant may be in the range of $10^{-12}$ to $10^{-14}$ M. This explains why incubation periods had to be extended compared to standard FVIII assays.

Results of a screening for an IgG mediated FVIII-like activity in hybridoma cell culture supernatants of a master plate are shown in Fig. 2. Supernatants were examined in a chromogenic FVIII assay. Shown are the results derived from the fifth master plate of fusion experiment number #193 (Balb/c mice immunized with

FIXaα). Absorbance was read after 4 hours of incubation at 37°C. Position ES was identified as exhibiting FVIII like activity significantly higher than the blank (MLW). This cell pool was designated 193/C0 and was further subcloned (Figure 3). As each well of the master plate contains more than one hybridoma cell clone, cells of a single positive well were expanded and plated at a calculated cell density of 2 - 0.2 cells/well on a 96 well plate. Again, the supernatants were tested for FVIII-like activity and positive positions were subjected to another round of subcloning. Typically three to four rounds of subcloning were performed with each clone displaying FVIII-like activity to obtain homogenous cell populations. Here the results of the chromogenic assay of the 193/C0 subclones are shown. Absorbance was read after a 4 hour incubation period at 37°C. Positions A6 and D5 exhibited substantial FVIII-like activity and were named 193/M1 and 193/P1, respectively. These two clones were subjected to another round of subcloning. As a negative control plain cell culture medium was assayed on each plate (MLW(H1)).

A comparison of chromogenic FVIII-like activity and FIX-ELISA reactivity of small scale (3 ml) hybridoma cultures is shown in Fig. 4. Before a decision was made whether a master clone (or subclone) was to be further subcloned, clones were grown at a 3-5 ml scale and the supernatants were checked again. This graph shows the FIX specific ELISA results and the FVIII-like chromogenic activity of the master clone 193/C0 and all its subclones which were identified as positives and re-checked. Blanks (absorbency of the chromogenic reagent itself) were subtracted in the case of the ELISA as well as the chromogenic assay readings depicted here. Clone 193/M1 was subcloned and yielded clones 193/V2, 193/M2 and 193/U2. The other clones of the 2nd round came from 193/P1, 193/AB2 and 193/P2 were subcloned. 193/AF3, 193/AB3 and 193/AE3 are subclones of 193/AB2. The other

clones of the 3rd round came from 193/P2. Finally 193/AF3 (→193/AF4), AE3 (→193/AE4, 193/AL4, 193/AN4 and 193/AO4) and 193/AD3 (→193/AG4, 193/AH4, 193/AD4, 193/AI4, 193/AK4) were subcloned.

From each fusion experiment, several (5-15) master clones (selected from the master plate) were identified and subjected to subcloning. After 3 rounds of subcloning, most of the cell lines were homogenous as demonstrated by ELISA and chromogenic activity analysis (see Fig. 4) as well as by cDNA sequence analysis. A specific master clone and all its subclones produce the same FIX/FIXa binding antibody. However, there are huge differences in the antibody protein sequences of clones derived from different master clones (see Example 11). Most hybridoma cell lines express antibodies from the IgG subclass (i.e. clones #193, #198, like 198/A1, 198/B1, 198/BB1). However, we were also able to select some clones expressing IgM antibodies.

The chromogenic activity of hybridoma supernatant of some important master clones and subclones was determined. Absorbance was measured after a 1h 30 min and 3h 30 min incubation period at 37°C (Fig. 5). In contrast to all the clones from the 193rd fusion, clone 196/C0 and its subclone 196/AP2 produced a FIX/FIXa-specific IgM antibody that gave a strong chromogenic activity even after a short period of incubation.

The following cell lines have been deposited with the European Collection of Cell Cultures (ECACC) in accordance with the Budapest Treaty: 98/B1 (ECACC No. 99090925); 198/A1 (ECACC No. 99090924); 198/BB1 (ECACC No. 99090926); 193/AO (ECACC No. 99121614); 196/C4 (ECACC No. 99121615); 198/D1 (ECACC No. 99121616); 198/T2 (ECACC No. 99121617); 198/G2 (ECACC No. 99121618); 198/AC1 (ECACC No. 99121619); and 198/U2 (ECACC No. 99121620).

To do a more in depth analysis of the biochemical properties of certain antibodies, homogenous hybridoma

cell lines expressing different antibodies with FVIII-like activity were expanded and used to express the antibody in question on a larger scale (100-1000 ml). These antibodies were affinity purified (see Example 3) prior to being used in further experiments.

**Example 3: Factor IX/FIXa$_{(\alpha,\beta)}$ binding properties of antibodies exhibiting FIX/FIXa activating activity**

Factor IX and the two activated forms of FIX, FIXa$\alpha$ and FIXa$\beta$ (FIX/FIXa$_{(\alpha,\beta)}$) were diluted in TBS (25mM Tris HCl, 150mM NaCl, pH 7.5) to a final concentration of 2µg/ml. Nunc Maxisorp ELISA plates were coated with 100µl FIX/FIXa$_{(\alpha,\beta)}$ sclution according to standard procedures (4°C, overnight) and washed several times with TBST (TBS, 0.1% (v/v) Tween 20). 50µl hybridoma supernatant was diluted 1:1 with 50µl TBST/2%BSA and added to the coated ELISA plate. After an incubation period of 2h at room temperature (RT), plates were washed 4 times with TBST and incubated (2h, RT) with 100µl/well of a 1:25000 dilution (in TBST/1%BSA) of an anti-mouse IgG (Fc-specific) peroxidase conjugated antibody (Sigma, #A-0168). Wells were washed 5 times with TBST and finally stained with 100µl freshly prepared staining solution (10ml 50mM sodium citrate, pH 5 supplemented with 100µl OPD (60mg OPD/ml) and 10µl 30% $H_2O_2$). The reaction was stopped by the addition of 50ml $H_2SO_4$ and the optical density recorded at 492nm and 620nm in a Labsystems iEMS Reader MF$^{TM}$ microtiter plate reader employing GENESIS$^{TM}$ software.

In certain cases, instead of an anti-mouse IgG ELISA, an anti-mouse IgM ELISA was carried out.

**Purification of mouse-IgG from hybridoma cell culture supernatants**

Hybridoma supernatant (100-500 ml) was supplemented with 200 mM Tris/HCl buffer (pH 7.0) and solid NaCl to

give final concentrations of 20 mM Tris and 3M NaCl, respectively. The supernatant was then clarified by centrifugation at 5500 x g for 10 minutes. A 1 ml protein G affinity chromatography column (Protein G Sepharose Fast Flow, Amersham-Pharmacia) was washed with 15 ml 20 mM Tris/Cl pH 7.0 and afterwards equilibrated with 10 ml of 20 mM Tris/Cl buffer pH 7.0 containing 3M NaCl. The hybridoma supernatant containing 3M NaCl was then loaded onto the column by gravity. The column was washed with 15 ml of 20 mM Tris/Cl buffer, pH 7.0, containing 3M NaCl. Bound IgG was further eluted with 12 ml glycine/HCl buffer pH 2.8 and 1 ml fractions were collected. 100µl of 1M Tris pH 9.0 were added to each fraction for neutralization. Fractions containing the IgG were identified by mixing 50µl with 150µl of a staining solution (BioRad concentrate, 1:5 diluted with water) in wells of a microplate. Positive fractions were pooled, concentrated to 1 ml in an ultrafiltration concentrator device (Centricon Plus 20, Amicon) according to the manufacturer. The concentrate was diluted with 19 ml TBS (20 mM Tris/Cl buffer pH 7.0 containing 150mM NaCl) and again concentrated to 1 ml. The diluting-concentrating step was repeated for two more times in order to bring IgG into TBS.

**Purification of mouse-IgM from hybridoma cell supernatants**

100-500 ml of hybridoma cell culture supernatant were concentrated to 5-10 ml either with an ultra-filtration concentrator device (Centricon Plus 20, Amicon) according to the manufacturer or by ammonium sulfate precipitation (40% saturation, 0°C) and redissolving the precipitate with 5-10 ml of TBS. In either case the concentrate was dialyzed against 20mM Tris Cl buffer pH 7.4 containing 1.25M NaCl and further concentrated to 1 ml in a Centricon Plus 20, (Amicon) ultrafiltration device. IgM was purified from this

concentrate with the ImmunoPure IgM Purification Kit (Pierce) according to the manufacturer. Fractions collected during elution from the maltose binding protein-column were tested for IgM, pooled, concentrated and brought into TBS as described for IgG.

**Determination of IgG concentrations in purified preparations**

Total IgG content 280nm - extinction of appropriate dilutions were measured. E280 = 1.4 corresponds to 1 mg/ml protein.

**Factor IXa specific IgG (quantitative ELISA)**

Wells of a microplate (Nunc Maxisorp) were incubated with 2µg/ml factor IXa diluted in TBS (25mM Tris/HCl pH 7.5 containing 150mM NaCl) overnight at 4°C. Wells were washed four times with TBST (25mM Tris/HCl pH 7.5 containing 150mM NaCl and 0.1% (v/v) Tween 20®. As a standard monoclonal AB the HIX1 anti-FIX (accurate) was used. Standard and samples were diluted in TBST containing 2%(w/v) BSA. The standard dilution series and appropriate dilutions of the samples were incubated on the ELISA-plate for 2 hours at room temperature. Plates were washed 4 times with TBST and incubated (2h, RT) with 100µl/well of a 1:25000 dilution (in TBST/1%BSA) of an anti-mouse IgG (Fc-specific) peroxidase conjugated antibody (Sigma, #A-0168) FIXa. Wells were washed 5 times with TBST and finally stained with 100µl freshly prepared staining solution (10ml 50mM sodium citrate, pH 5 supplemented with 100µl OPD (60mg OPD/ml) and 10µl 30% $H_2O_2$). The reaction was stopped by the addition of 50ml $H_2SO_4$ and after 30 minutes the optical density was recorded at 492nm and 620nm in a Labsystems iEMS Reader MF™ microtiter plate reader employing GENESIS™ software.

**Example 4: Anti-FIX/FIXa antibodies exhibiting FVIII-like activity in a chromogenic FVIII assay**

Several anti-FIX/FIXa antibody producing hybridoma clones were subcloned up to four times and the resulting monoclonal hybridoma cell line used to produce monoclonal antibody containing supernatant. IgG isotype antibodies derived from these supernatants were purified over affinity columns and dialyzed against TBS (see above). IgM antibodies were used as unpurified supernatant fractions. The following experiments were done with two sets of representative antibodies: 193/AD3 and 198/AC1/1 (IgG isotype, the antibody 198/AC1/1 is a preparation from the parent 198/AC1 hybridoma clone, i.e. that a (frozen) vial containing 198/AC1 cells is cultivated and antibodies are produced. The supernatant is then used for these experiments.) and 196/AF2 and 196/AF1 (IgM isotype) (Fig. 6A and Fig. 6B). Briefly, 25µl aliquots of monoclonal antibody containing sample (unpurified hybridoma supernatant or, where indicated, a certain amount of FIX specific antibody) were transferred to microtiter plate wells and warmed to 37°C. Chromogenic substrate (S-2222), synthetic thrombin inhibitor (I-2581), factor (F) IXa and FX were reconstituted in sterile water and FIXa/FX was mixed with phospholipids according to the supplier's protocol. Per reaction, 50µl of the phospholipid/FIXa/FX solution were combined with 25µl $CaCl_2$ (25mM) and 50µl of the substrate/inhibitor cocktail. To start the reaction, 125µl of the premix were added to the monoclonal antibody solution in the microtiter plates and incubated at 37°C. Absorbance at 405nm and 490nm of the samples was read at various times (5min to 6h) against a reagent blank (cell culture medium instead of hybridoma supernatant) in a Labsystems iEMS Reader MF™ microtiter plate reader using GENESIS™ software.

The time course of FVIII-like activity exhibited by monoclonal antibodies 193/AD3 (IgG isotype) and 196/AF2 (IgM isotype) compared to human FVIII (12 and 16mU/ml),

TBS and to cell culture medium is shown in Fig. 6A. After a lag phase, both antibodies give rise to chromogenic substrate cleavage, as judged by the increasing optical density measurable at 405nm wavelength.

The time course of FVIII-like activity exhibited by monoclonal antibodies 198/AC1/1 (IgG isotype, 10µg/ml) and 196/AF1 (IgM isotype, unpurified supernatant) compared to human FVIII (16mU/ml) and 10µg/ml of mouse IgG is shown in Fig. 6B. After a lag phase, both antibodies give rise to chromogenic substrate cleavage, as judged by the increasing optical density measurable at 405nm wavelength.

**Example 5: FVIII-like activity exhibited by anti-FIX/FIXa-antibodies generates factor Xa and is phospholipid, FIXa/FX and $Ca^{2+}$ dependent.**

Factor VIII activity is usually determined with a chromogenic assay and/or an APTT-based clotting assay. Both types of assays rely on FVIIIa/FIXa-mediated factor Xa generation. In the case of a chromogenic FVIII assay, the factor Xa produced will subsequently react with a chromogenic substrate, which can be monitored spectroscopically, e.g., in an ELISA reader. In an APTT based clotting assay free factor Xa will assemble with FVa on a phospholipid surface in the so-called prothrombinase complex and activate prothrombin to thrombin. Thrombin in turn gives rise to fibrin generation and finally to clot formation. Central to the two assay systems is generation of factor Xa by the FVIIIa/FIXa complex.

To demonstrate that the FVIII-like activity exhibited by anti-FIX/FIXa-antibodies indeed generates factor Xa, the following experiment was carried out. Several 25µl aliquots of unpurified hybridoma supernatant 196/AF2 (IgM isotype) were transferred to microtiter plate wells and warmed to 37°C. As a positive

control, 16mU of Recombinate™ were diluted into hybridoma medium (196 HM 007/99) and treated exactly the same way as the hybridoma supernatant. As a negative control, plain hybridoma medium was used. Chromogenic substrate (S-2222), synthetic thrombin inhibitor (I-2581), factor IXa and FX were reconstituted in sterile water and FIXa/FX was mixed with phospholipids according to the supplier's protocol. Pefabloc Xa®, a factor Xa specific proteinase inhibitor (Pentapharm, LTD), was reconstituted with water to a final concentration of 1mM/l. Per reaction, 50µl of the phospholipid/FIXa/FX solution were combined with 25µl $CaCl_2$ (25mM) and 50µl of the substrate/thrombin-inhibitor cocktail. To start the reaction, 125µl of the premix were added to the samples in the microtiter plates and incubated at 37°C. Where indicated, 35µM Pefabloc Xa® were added. Absorbance at 405nm and 490nm was read at various times (every 5 minutes to 6h) against a reagent blank (cell culture medium) in a Labsystems iEMS Reader MF™ microtiter plate reader employing the GENESIS™ software.

The results of the factor IXa stimulation by the FVIII-like activity exhibited by the IgM anti- FIX/FIXa-antibody 196/AF2 in generating actor Xa as judged by the readily measurable cleavage of the chromogenic substrate S-2222 (compare "16mU FVIII" and "196/AF2") is shown in Fig. 7A. Factor Xa activity is effectively blocked by the FXa specific inhibitor "Pefabloc Xa®" (compare "196/AF2" versus "196/AF2 35µM Pefabloc Xa®") indicating that indeed FXa was generated.

The same experiment was performed using purified IgG preparations of clone 198/AM1 (Fig. 7B). Purified IgG was diluted in TBS to a final concentration of 0,4mg/ml and 25µl (i.e. a total of 10µg), transferred to microtiter plate wells and warmed to 37°C. As a positive

control, 6mU plasma- derived FVIII was used. 10µg unspecific mouse IgG (Sigma, I-5381) served as a negative control. The assay was performed as described above.

Further experiments show the factor IXa stimulation by the FVIII-like activity exhibited by the IgG anti-FIX/FIXa-antibody 198/AM1 generates factor Xa as judged by the readily measurable cleavage of the chromogenic substrate S-2222 (Fig. 7B). Again factor VIII and antibody 198/AM1 generate FXa which is effectively blocked by the FXa specific inhibitor "Pefabloc Xa®". As a negative control, unspecific mouse IgG (Sigma, I5381) was assayed.

In another set of experiments, the dependence of the FVIII-like activity of either purified anti-FIX/FIXa-antibodies (IgM, Fig.8A) or of unpurified antibodies derived from cell culture supernatants (IgG, Fig. 8B) on the presence of phospholipids (PL), FIXa/FX and $Ca^{2+}$ was demonstrated. Mouse IgG was used as a control (Fig. 8C). Factor VIII-like activity was assayed essentially as described above. When indicated, either the FIXa/FX mixture, the PL or $Ca^{2+}$ was omitted from the reaction. Absorbency at 405nm and 490nm of the samples was read at various times against a reagent blank (buffer instead of purified antibody) in a Labsystems iEMS Reader MF™ microtiter plate reader. The results are shown in Fig. 8A, Fig. 8B and Fig. 8C.

The dependence of the FVIII-like activity of purified anti-FIXa-antibody 198/AC1/1 (IgG isotype, concentration used throughout the assay was 10µg/ml) on the presence of phospholipids (PL), FIXa/FX and $Ca^{2+}$ is further shown in Fig. 8A. As is easily recognizable, only the complete assay, including antibody, PL, $Ca^{2+}$, and FIXa/FX gives rise to a reasonable FXa generation. The dependence of the FVIII-like activity of cell culture supernatant containing unpurified IgM isotype

anti-FIX/FIXa-antibody (196/AF1) on the presence of phospholipids, FIXa/FX and $Ca^{2+}$ is shown in Fig. 8B.

Again, as already shown for the purified IgG preparation (Fig. 8A), antibody 198/AC1/1, only the complete assay, including PL, $Ca^{2+}$, FIXa/FX, will give a reasonable amount of FXa generation. To demonstrate the specificity of the reaction, total IgG prepared from normal mouse plasma was assayed under the same conditions as above. The results are shown in Fig. 8C. No FVIII-like activity could be detected. There is, as expected, no activity detectable in the absence of phospholipids, FIXa/FX and $Ca^{2+}$. All experiments were done in a microtiter plate and the OD405 was scanned every 5 minutes for 6h.

**Example 6: Certain anti-FIX/FIXa-antibodies are procoagulant in the presence of FIXa**

During normal hemostasis, FIX becomes initially activated either by the tissue factor (TF)/factor VIIa pathway or later on by activated factor XI (FXIa). Subsequent to its activation, FIXa associates on the platelet surface in a membrane bound complex with activated FVIII. Factor IXa by itself has little or no enzymatic activity towards FX, but becomes highly active in the presence of FVIIIa. To demonstrate that certain anti-FIX/FIXa antibodies have FVIII-like activity and hence are procoagulant in a FVIII deficient human plasma, the following experiment was carried out. Different amounts of antibody 193/AD3 or mouse IgG (as a control) were used in a standard aPTT based one stage clotting assay. Briefly, 100µl of antibody-containing samples were incubated with 100µl of FVIII deficient plasma (DP) and with 100µl of DAPTTIN (PTT Reagent for determining activated Thromboplastin Time; IMMUNO AG) reagent, in a KC10A clotting analyzer. Where indicated, a total amount of 50ng activated FIX was included in the reaction mixture. After a 4 minute incubation, the

reaction was started by the addition of 100µl $CaCl_2$ (25mM). The results are shown in Table 1 and Fig. 9.

**clotting time (sec)**

| µg AB | 193/AD3 | mouse IgG |
|---|---|---|
| | 50ng FIXa | 50ngFIXa |
| 9 | 101.6 | 102.5 |
| 4.5 | 95.6 | 103.2 |
| 2.25 | 93.1 | 103.2 |
| 1.8 | 93.7 | 101.9 |
| 1.35 | 91.4 | 103.4 |
| 0.9 | 94.4 | 102.2 |
| 0.45 | 98.1 | 101.9 |
| 0.34 | 97.1 | 103.9 |
| 0.23 | 99.3 | 103.7 |

Table 1: Clotting times of FVIII deficient plasma in an APTT based clotting assay employing various amounts of procoagulant (193/AD3) and control antibody (mouse IgG) in the presence of 50ng activated FIX (0.01UFIX). The molar ratio of antibody in the reaction and activated FIX is 10:1. The molar ratio between antibody and total FIX (FIX and FIXa, assuming that human FVIII deficient plasma contains 1U (5µg) FIX) varies between 6:1 (9µg antibody in reaction) and 1:6 (0.23µg antibody in reaction). At the optimal shortening of the clotting time, the molar ratio between antibody and total FIX is 1:1. The clotting time without the addition of FIXa is in the range of 120 seconds.

Fig. 9 is a graphical representation of the clotting times of FVIII deficient plasma in an aPTT based clotting assay employing various amounts of procoagulant (193/AD3) and control (mouse IgG) antibody in the presence of 50ng activated FIX. There is a clear dose-dependent reduction of the clotting time in samples supplemented with antibody 193/AD3. These results imply

that antibody 193/AD3 is procoagulant in the presence of FIXa.

**Example 7: Anti-FIX/FIXa-antibodies are procoagulant in the presence of FVIII inhibitors and FIXa**

A severe complication of the standard FVIII substitution therapy is the development of alloantibodies directed against FVIII, leading to FVIII neutralization and a condition where the patient's blood will not clot.

To demonstrate that certain anti-FIXa-antibodies have FVIII-like activity even in the presence of FVIII inhibitors, the following experiment was carried out. Different amounts of antibody 193/AD3 or, as a control, mouse IgG were used in a standard APTT based one-stage clotting assay. Briefly, 100µl antibody samples were incubated with either 100µl of FVIII deficient plasma (Fig.10A) or FVIII inhibitor plasma (inhibitor potency 400BU/ml), Fig.10B) as well as with 100µl of DAPTTIN reagent, in a KC10A clotting analyzer. In addition, a total amount of 50ng activated FIXa was included in the reaction mixture. After a 4 minute incubation, the reaction was started by the addition of 100µl $CaCl_2$ (25mM). To ensure equal conditions, the experiments employing FVIII deficient plasma and FVIII inhibitor plasma were done side by side. The results are shown in Fig. 10A and 10B. As already shown in Example 6, there is a clear dose-dependent reduction of the clotting time in samples supplemented with antibody 193/AD3 in the presence of FVIII inhibitors.

**Example 8: Anti-FIX/FIXa-antibodies are procoagulant in the presence of defective FVIII and FIXa**

To demonstrate that certain anti-FIXa-antibodies have FVIII-like activity in the presence of defective FVIII, the following experiment may be carried out.

Increasing amounts of antibody 193/AD3 or, as a control, mouse IgG are used in a standard aPTT-based one stage clotting assay. In this clotting assay, a hemophilia A patient's plasma having very low clotting activity due to the presence of defective FVIII (DF8) is used. Briefly, 100µl antibody samples are incubated with either 100µl of DF8 plasma or FVIII deficient plasma as well as with 100µl of DAPTTIN reagent, in a KC10A clotting analyzer. In addition, a total amount of 50ng activated FIXa is included in the reaction mixture. After a short incubation, the reaction will be started by the addition of 100µl $CaCl_2$ (25mM). To ensure equal conditions, the experiment employing FVIII deficient plasma and DF8 plasma is done side by side.

**Example 9: Anti-FIX/FIXa-antibodies with procoagulant activity in the presence of FIXa distinguish between human and bovine FIXa**

FIX/FIXa specific monoclonal antibodies selected from the 198$^{th}$ fusion experiment were purified from the respective hybridoma supernatant and quantified as described in Example 3. These antibodies were analyzed in a modified one-stage clotting assay (as described in Example 6) and some showed procoagulant activity.

The chromogenic activity of these antibody preparations was measured in the following FXa generation kinetic assay: 10µg of monoclonal antibody (in 25µl) were transferred to microtiter plate wells and warmed to 37°C. Chromogenic substrate (S-2222), synthetic thrombin inhibitor (I-2581), factor IXa and FX were reconstituted in sterile water and FIXa/FX (both bovine) were mixed with phospholipids according to the supplier's protocol. Per reaction, 50µl of the phospholipid/FIXa/FX solution were combined with 25µl $CaCl_2$ (25mM) and 50µl of the substrate/inhibitor

cocktail. To start the reaction, 125µl of the premix were added to the monoclonal antibody solution in the microtiter plates and incubated at 37°C. Absorbance at 405nm and 490nm of the samples was read at various times (5min to 2h) against a reagent blank (25ml TBS instead of monoclonal antibodies) in a Labsystems iEMS Reader MF$^{TM}$ microtiter plate reader using GENESIS$^{TM}$ software. In parallel, the same reactions were performed except that 50ng human FIXa were added per reaction. Those antibodies that showed procoagulant activity had no chromogenic activity in the case of bovine FIX, but displayed high activity when human FIXa was present.

Fig. 11 shows the time course of the FVIII-like activity exhibited by the monoclonal antibodies 198/A1, 198/B1 and 198/AP1 with (+) and without (-) addition of 50ng human FIXaβ. Non-specific polyclonal mouse IgG was used as a control. 198/A1 and 198/B1 show procoagulant activity (similar as 193/AD3 in example 6) whereas 198/AP1 does not. Antibody 198/BB1 had the same activity pattern (data not shown).

Further monoclonal antibodies selected from the 198$^{th}$ fusion experiment include 198/D1 (ECACC NO. 99121616), 198/T2 (ECACC No. 99121617), 198/G2 (ECACC No.9912118), 198/U2 (ECACC No. 99121620).

**Example 10: Structure and procoagulant activity of antibody derivatives derived from anti-FIX/FIXa-antibodies; Subcloning antibody variable domains from hybridoma cell lines 193/AD3, 193/K2, 198/A1 and 198/B1 (clone AB2)**

Cloning procedure: Messenger RNA was prepared from 1x10$^{6}$ hybridoma cells of the respective cell line (either 193/AD3, 193/K2, 198/A1 or 198/B1 (clone AB2)) employing the "QickPrep® Micro mRNA Purification Kit" (Pharmacia) according to the manufacturer's instructions. The corresponding cDNA was produced by retro transcription of mRNA using the "Ready-To-Go-You-

Prime-First-Strand Beads kit" (Pharmacia) according to the manufacturer's instructions. Heavy and light chain encoding sequences were converted to the corresponding cDNA employing a set of primers. To reverse transcribe heavy chain-specific mRNA (VH), an equimolar mixture of the oligonucleotides MOCG1-2FOR (5' CTC AAT TTT CTT GTC CAC CTT GGT GC 3') (SEQ.ID.NO. 1), MOCG3FOR (5' CTC GAT TCT CTT GAT CAA CTC AGT CT 3') (SEQ.ID.NO. 2) and MOCMFOR (5' TGG AAT GGG CAC ATG CAG ATC TCT 3') (SEQ.ID.NO. 3) was used (RTmix1). In the same reaction tube, light chain-specific cDNA (VL) was synthesized using primer MOCKFOR -(5' CTC ATT CCT GTT GAA GCT CTT GAC 3') (SEQ.ID.NO. 4).

The coding sequences for VH were amplified by PCR using the primer-sets depicted in Fig. 12 and the specific cDNA, derived from the reverse transcription mixture (RTmix1) described above, as the template. VK-chain genes were amplified using the primer sets depicted in Fig. 13 and also employing Rtmix1 as a template. The VH-PCR product was cleaved SfiI-AscI and inserted into SfiI-AscI digested vector pDAP2 (GeneBank accession no.: U35316). The pDAP2-VH constructs obtained thereby were named pDAP2-193AD3/VH, pDAP2-198A1/VH, pDAP2-198AB2/VH (derived from antibody 198/B1) and pDAP2-193/K2/VH, respectively. The plasmids were subsequently cleaved with AscI-NotI and the corresponding AscI-NotI digested VK-gene PCR product was inserted. The resultant vectors were designated pDAP2-193/AD3scFv, pDAP2-198/A1scFv, pDAP2-198/AB2scFv (derived from antibody 198/B1) and pDAP2-193/K2scFv and code for the VH-gene and the VL-gene of the monoclonal antibodies 193/AD3, 198/A1, 198/AB2 (derived from antibody 198/B1) and 193/K2. Heavy and light chains are linked by the coding sequence for an artificial, flexible linker ($G_4SGGRASG_4S$; Engelhardt et al., 1994) and enables expression of the scFv variant of the respective antibody.

In Fig. 14, the DNA and the deduced protein sequence of the scFv derived from the hybridoma cell line 193/AD3 are depicted. Nucleotides 1 to 357 code for the heavy chain variable domain, nucleotides 358 to 402 code for the artificial flexible linker and nucleotides 403 to 726 code for the light chain variable region. The protein sequence of the CDR3 region of the heavy chain has the sequence YGNSPKGFAY (SEQ.ID.NO. 5) and is given in bold letters. The artificial linker sequence ($G_4SGGRASG_4S$) is shown.

In Fig. 15, the DNA and the deduced protein sequence of the scFv derived from the hybridoma cell line 193/K2 is shown. Nucleotides 1 to 363 code for the heavy chain variable domain, nucleotides 364 to 408 code for the artificial flexible linker, and nucleotides 409 to 747 code for the light chain variable region. The protein sequence of the CDR3 of the heavy chain has the sequence DGGHGYGSSFDY (SEQ.ID.NO. 6), and is given in bold letters. The artificial linker sequence ($G_4SGGRASG_4S$) is show.

In Fig. 16, the DNA and the deduced protein sequence of the scFv derived from the hybridoma cell line 198/AB2 (derived from antibody 198/B1) are depicted. Nucleotides 1 to 366 code for the heavy chain variable domain, nucleotides 367 to 411 code for the artificial flexible linker, and nucleotides 412-747 code for the light chain variable region. The protein sequence of the CDR3 region of the heavy chain has the sequence EGGGFTVNWYFDV (SEQ.ID.NO. 7) and is given in bold letters. The artificial linker sequence ($G_4SGGRASG_4S$) is also shown.

In Fig. 17, the DNA and the deduced protein sequence of the scFv derived from the hybridoma cell line 198/A1 are depicted. Nucleotides 1 to 366 code for the heavy chain variable domain, nucleotides 367 to 411 code for an artificial flexible linker, and nucleotides 412-747 code for the light chain variable region. The

protein sequence of the CDR3 region of the heavy chain has the sequence EGGGYYVNWYFDV (SEQ.ID.NO.8 ) and is given in bold letters. The artificial linker sequence ($G_4SGGRASG_4S$) is also shown.

**Example 11: Procoagulant activity of peptides derived from CDR3 regions of anti-FIX/FIXa-antibodies**

In principle, the antibody molecule can be envisioned as a biological device for the presentation of a combinatorial array of peptide elements in three dimensional space (see Gao et al., 1999, PNAS, 96:6025). Therefore, an antibody (or an antibody derivative, e.g. scFv, Fab, etc.) can be used either as a tool for the detection of functionally important domains of a specific target protein, or on the other hand, for the delineation of amino acid sequences specifically mediating certain interactions, i.e. activating or enhancing the activity of FIXa towards the physiological substrate FX. The latter process has led to the evaluation of a number of heavy chain CDR3 region ($CDR3_H$) derived peptide sequences as FIXa enhancing agents.

Enhancing the procoagulant activity of peptides which exhibit such activity may be accomplished through sequence variation within the peptide regions critical for mediating the FIXa activity enhancement. As a possible step towards peptide sequences with enhanced procoagulant activity, the binding site of an antibody, i.e. 198/A1 or 198/B1, on the FIXa molecule is mapped by employing sequence comparison analyses, competitive binding assays, Western blot analyses and competitive ELISA analyses. Since the crystal structure of FIX is known, molecular modeling is subsequently used to improve the fitting of i.e. 198/B1 derived peptides in the 198/B1 binding site on human FIXa.

On the other hand, methodical mutational analysis of a given peptide sequence such as 198/A1 or 198/B1

$CDR3_H$ derived peptide sequences by, e.g., "alanine scanning mutational analysis" allows for the identification of peptide residues critical for procoagulant activity. Another way to improve the activity of a certain peptide sequence is the use of peptide libraries combined with high throughput screening.

The antigen binding site of an antibody is derived from the juxtaposition of the six "complement determining regions (CDR's)" at the N-terminal end of the VL-HL dimer (or Fv region). The contribution of a single CDR to the antibody specificity for a given antigen may vary considerably, but in general it is thought that the CDR3 region of the heavy chain ($CDR3_H$) is of special influence, i.e. the particular protein sequence of $CDR3_H$ region may be highly important for antigen recognition. The length of $CDR3_H$ regions has been reported to vary considerably and is in the range of 4-25 amino acids (Borrebaeck, p.16).

An example of a methodical mutational analysis of peptide sequences is given below. To improve the solubility/procoagulant efficacy of peptides derived from the CD3-region of anti FIX/FIXa antibodies, the N-terminal as well as the C-terminal amino acid sequences were changed. In addition, a series of mutated peptides was constructed and analyzed.

The principle of such a study is exemplified by a series of peptides derived from $CDR3_H$ region of antibodies 198/A1 and 198/B1. The original peptide A1(see table 2) is derived from the $CDR3_H$ region of antibody 198/A1 and peptide B1 is derived from the $CDR3_H$ region of antibody 198/B1, respectively (see example 10, Fig. 16 and 17). The term "scrambled version" means that a peptide has the same amino acids but in random order.

| Peptide | Sequence | Amino-acids | MW (D) | pI | Remark |
|---|---|---|---|---|---|
| A1 | EGGGYYVNWYFDV (SEQ.ID.No. 9) | (13aa) | 1569 | 7.2 | Decreased solubility |
| A1/1 | VYGFGWGYEVNDY (SEQ.ID No. 10) | (13aa) | 1569 | 7.1 | Scrambled version of A1, |
| A1/2 | EEERGGGYYVNWYFDEEE (SEQ.ID No. 11) | (18aa) | 2244 | 5.8 | Acidic pI, soluble, |
| A1/3 | RRREGGGYYVNWYFDRRR (SEQ.ID.No. 12) | (18aa) | 2407 | 9.9 | Basic pI, soluble, |
| A1/4 | EYGRGYGEVNEYDEFEWE (SEQ.ID.No. 13) | (18aa) | 2244 | 5.8 | Scrambled version of A1/2 |
| A1/5 | VRYRNRYRWGYRGRFGDE (SEQ.ID.No. 14) | (18aa) | 2407 | 9.9 | Scrambled version of A1/3 |
| A1/3-scr3 | RRRGEYGVYWNGDFYRRR (SEQ.ID.No. 15) | (18aa) | 2407 | 9.9 | Scrambled version of A1/3 |
| A1/3-Rd | RdRdRdEGGGYYVNWYFDRdRdRd (SEQ.ID.No. 16) | (18aa) | 2407 | 9.9 | Peptide A1/3 but substitute D-Arg for L-Arg |
| A1/3-Rd-srmb | RdRdRdGEYGVYWNGDFYRdRdRd (SEQ.ID.No. 17) | (18aa) | 2407 | 9.9 | Scrambled version of A1/3-Rd |

Table 2
List of a series of antibody 198/A1 derived peptides. Listed are the length of the peptide (aa, amino acids #), the calculated molecular weight (MW, in Dalton (D) and the statistical isoelectric point (pI).D-Arg is abbreviated as Rd.

In a first series of experiments we improved the solubility of the original $CDR3_H$ peptide sequence (A1; EGGGYYVNWYFDV) by removing the C-terminal Val residue and adding several charged residues at the N- as well as the C-terminal end of the peptide. The resulting peptides, A1/2 (acidic pI), A1/3 (basic pI) and their respective scrambled versions A1/4, A1/5 and A1/3scr3 were readily soluble in a variety of buffer systems at physiological pH.

To analyze the FVIII-like (FIXa activating) activity of the peptides, an assay system based on a commercial available FVIII assay was developed (see examples 2 and 4). The basic principle is, that without a cofactor, FIXa will have very limited activity towards its natural substrate FX. Only in the presence of a substance having FIXa activation properties, i.e. FVIII or a substance exhibiting FVIII-like activity, a substantial amount of FXa is produced by cleavage of FX through the FIXa/activator complex. The amount of FXa generated is monitored by cleavage of a chromogenic substrate. The principle of the revised chromogenic assay is described for two representative peptides: A1/3 and A1/5 (Table 2). Briefly, 25µl aliquots of peptide stock solution (in imidazole buffer (IZ) 50mM imidazole, 100mM NaCl, pH7.2) were transferred to microtiter plate wells and warmed to 37°C. Chromogenic FXa substrate (S-2222), synthetic thrombin inhibitor (I-2581), bovine FIXa and bovine FX were reconstituted in sterile water and FIXa/FX mixed with phospholipids according to the supplier's protocol. Since the peptides do not react with bovine FIXa, (which comes as a mixture with bovine FX in the Test Kit) 2,9nM (in most cases 2.3nM) human FIXa (ERL) were added (see Example 11, Fig 19). Per reaction, 50µl of the phospholipid /FIXa/FX solution were combined with 25µl $CaCl_2$ (25mM) and 50µl of the substrate/inhibitor cocktail. To start the reaction, 125µl of the premix were added to the peptide solution in the microtiter plate and incubated at 37°C. Absorbance at 405nm and 490nm of the samples was read at various times (5 min to 2h) against a reagent blank in a Labsystems iEMS Reader MF$^{TM}$ microtiter plate reader using GENESIS$^{TM}$ software.

The result of this experiment are shown in Example 11, Fig 18. Peptide A1/3 induced a readily measurable

FXa generation in the presence of 2.9nM human FIXa, whereas the scrambled version A1/5 was inactive. In addition, the acidic peptide A1 2 as well as the scrambled versions A1/4 and A1/3-scr3 did not give any significant chromogenic activity when tested under comparable conditions (data not shown). To prove that the peptide A1/3 like the parental antibody 198/A1 does not react with bovine FIXa and FX the experiment shown in Fig. 19 was done. The peptide A1/3 was incubated as described above with (A1/3 (24$\mu$M), +hFIXa) and without (A1/3 (24$\mu$M), w/o hFIXa) 2.3nM human FIXa (hFIXa). In a control experiment we added plain dilution buffer (IZ) supplemented with 2.3nM hFIXa to the reaction mixture. As shown in Fig. 19, the reaction takes place only in the presence of human FIXa.

Fig. 18 demonstrates the chromogenic FVIII-like activity of peptide A1/3 in the presence of 2.9nM human FIXa (hFIXa). The scrambled version of peptide A1/3, peptide A1/5 does not give rise to any FXa generation. Fig. 19 demonstrates the dependence of the chromogenic FVIII-like activity of peptide A1/3 on the presence of human FIXa (hFIXa). In the absence of human FIXa, peptide A1/3 does not give rise to any FXa generation. The buffer control, plain imidazole buffer is designated IZ.

The peptides were also analyzed for their potential to reduce the clotting time in a FVIII deficient plasma. The aPTT based one stage clotting assay was essentially done as described (see example 6). Clotting times (time from starting the reaction to the "clot"-formation were compared either against FVIII, a buffer control (IZ) or a control peptide (scrambled version). The results of two typical clotting experiments done with two different aPTT reagents (IAPTTIN and Pathromtin SL) are shown in table 3A and table 3B.

| Exp. 1 | peptide conc. | w/o FIXa sec | w/ FIXa sec | average sec | 2.2nM FIXa sec | 2.2nM FIXa sec | average sec |
|---|---|---|---|---|---|---|---|
| IZ | 0 | 107.7 | 106.4 | 107 | 93.1 | 94.5 | 94 |
| A1/3 | 15µM | 78.2 | 77.1 | 78 | 59.3 | 59.4 | 60 |
| | 12.5µM | 80.2 | 80.4 | 80 | 60.2 | 59.9 | 60 |
| | 7.5µM | 97.6 | 97.9 | 98 | 73.1 | 72.7 | 73 |
| | 2.5µM | 105.2 | 104.8 | 105 | 91.1 | 91 | 91 |
| A1/3-scr3 | 15µM | 122.5 | 122 | 122 | 106.1 | 105.5 | 106 |
| | 12.5µM | 116 | 117.6 | 117 | 103.1 | 104.5 | 104 |
| | 7.5µM | 114.2 | 113.9 | 114 | 100.8 | 100.6 | 101 |
| | 2.5µM | 107.6 | 107.4 | 108 | 96.3 | 95.2 | 96 |
| Exp. 2 | peptide conc. | w/o FIXa sec | w/o FIXa sec | average (sec) | 2.2nM FIXa sec | 2.2nM FIXa sec | average (sec) |
| IZ | 0 | 111 | 109.7 | 110 | 94.7 | 95.5 | 95 |
| A1/3 | 12.5µM | 83.6 | 85.5 | 85 | 56.7 | 56.7 | 57 |
| | 10µM | 79.1 | 78.5 | 79 | 63.1 | 62.5 | 63 |
| | 7.5µM | 100.1 | 100.5 | 100 | 71.6 | 73.9 | 73 |
| | 5µM | 103.4 | 104.8 | 104 | 77 | 76 | 77 |
| | 2.5µM | 110.1 | 108.9 | 110 | 88 | 88.6 | 88 |
| | 1.25µM | 108.7 | 109.3 | 109 | 90.7 | 90.8 | 91 |

Table 3A. Clotting activity of peptides A1/3 and A1/3-scr (scrambled version of A1/3) in FVIII deficient plasma either in the presence or in the absence (w/o) of 2.2nM human FIXa. Shown are two independent representative experiments (Exp. 1 and Exp. 2). All clotting experiments have been done in duplicate. Given are the clotting times for the individual experiments and the average clotting time in seconds (sec). Experiments shown in table 3A have been done employing the aPTT reagent DAPTTIN (Baxter Hyland Immuno). Compared to the buffer control (IZ, imidazole buffer) the peptide A1/3 gave rise to a dose dependent reduction in the clotting time. The reduction in the clotting time became much more pronounced by the addition of 2.2nM activated human FIX to the reaction mix. The scrambled version of peptide A1/3, A1/3-scr3 did not show any reduction of the clotting time. In fact, at concentrations above 2.5µM, the scrambled peptide became

inhibitory and therefore prolonged the clotting time. Peptides A1/1, A1/2, A1/4 and A1/5 did not give any reduction in the clotting time indicating that they lack procoagulant activity (data not shown).

| | Final conc. | w/ FIXa sec | w/o FIXa sec | average sec | 2.2nM FIXa sec | 2.2nM FIXa sec | average sec |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| IZ | 0 | 131.8 | 132.1 | 132 | 107.9 | 108.7 | 108 |
| | | | | | | | |
| FVIII | 12.5mU/ml | 66.9 | 69 | 69 | 52.9 | 53.6 | 53 |
| | 6.25mU/ml | 77.6 | 77.9 | 78 | 58.6 | 58.9 | 59 |
| | | | | | | | |
| A1/3 | | | | | | | |
| | 15µM | 152.6 | 149.3 | 151 | 75.4 | 75.2 | 75 |
| | 10µM | 135.7 | 134.6 | 135 | 76.2 | 79.8 | 78 |
| | 5µM | 152.6 | 155.6 | 154 | 86.6 | 90.2 | 88 |
| | 1µM | 138.3 | 138.8 | 139 | 103.7 | 105.9 | 105 |

Table 3B. Clotting activity of peptide A1/3 in FVIII deficient plasma when Pathromtin SL (DADE Behring) is used as an aPTT reagent. The experiments were done in duplicate, either in the presence or in the absence (w/o) of 2.2nM human FIXa. Given are the clotting times for the individual experiments and the average clotting time in seconds (sec). Factor VIII and imidazole buffer (IZ) were included as positive and negative control respectively.

In contrast to the experiments shown in table 3A the experiments shown in table 3B have been done employing the aPTT reagent Pathromtin SL. In the presence of FIXa, the peptide A1/3 gave rise to a dose dependent reduction in the clotting time whereas in the absence of FIXa no reduction of the clotting time was detectable.

In another series of experiments we set out to improve the plasma stability (protection from, e.g., proteolytic degradation) of peptide A1/3. One approach was to substitute the N- and C-terminal L-Arg residues

with D-Arg residues (exemplified by peptides A1/3-rd and A1/3-Rd-srmb). Peptides A1/3-rd and A1/3-Rd-srmb (scrambled version of the peptide)were then analyzed in a chromogenic as well as in the aPTT based clotting assay. These experiments revealed that exchanging the terminal L-Arg residues for D-Arg residues did not change the FVIII-like activity as measured in the chromogenic assay, indicating that chirality of the Arg-residues does not play a major role in chromogenic activity (Fig. 20). In addition, the aPTT based one-stage clotting activity, although somewhat reduced, was still easily detectable (Table 4).

| | Peptide conc. | w/1 FIXa sec | w/2 FIXa, sec | **average sec** | 2.2nM FIXa sec | 2.2nM FIXa sec | **average sec** |
|---|---|---|---|---|---|---|---|
| IZ | 0 | 110 | 109.1 | **110** | 96 | 96 | 96 |
| A1/3 | 15µM | 77.8 | 78 | **78** | 56.1 | 55.5 | 56 |
| | 12.5µM | 99.4 | 100.5 | **100** | 68 | 68 | 67 |
| | 10µM | 104.4 | 104.5 | **104** | 72 | 73.2 | 73 |
| | 7.5µM | 105.2 | 105.2 | **105** | 80.7 | 80.5 | 81 |
| | 5µM | 108.4 | 107.7 | **108** | 89.7 | 88.3 | 89 |
| | 2.5µM | 107.9 | 107.6 | **108** | 93.6 | 93.3 | 93 |
| | 1.25µM | 106.7 | 107 | **107** | 94.4 | 95 | 95 |
| A1/3-Rd | 15µM | 96.4 | 95.4 | **96** | 76.1 | 74.4 | 75 |
| | 12.5µM | 98 | 98.6 | **98** | 72.3 | 73.7 | 73 |
| | 10µM | 93.5 | 96.8 | **95** | 74.2 | 77.2 | 76 |
| | 7.5µM | 97.6 | 98.1 | **98** | 80.9 | 82.2 | 82 |
| | 5µM | 99.2 | 99.1 | **99** | 86 | 85.1 | 86 |
| | 2.5µM | 102.7 | 103.4 | **103** | 94.4 | 94.7 | 95 |
| | 1.25µM | 107.5 | 107.7 | **108** | 96.6 | 96 | 96 |
| A1/3-Rd srmb | 15µM | 121.9 | 121.3 | **122** | 112.7 | 112.4 | 113 |
| | 12.5µM | 117.2 | 118 | **118** | 108.1 | 107.8 | 108 |
| | 10µM | 115.8 | 115.3 | **116** | 107.2 | 107.8 | 108 |
| | 7.5µM | 114.6 | 113.6 | **114** | 107.6 | 106.6 | 107 |
| | 5µM | 113.1 | 112.4 | **113** | 108.5 | 108.2 | 108 |
| | 2.5µM | 111.9 | 111.9 | **112** | 105 | 104.2 | 105 |
| | 1.25µM | 107.2 | 107.1 | **107** | 101.1 | 105.3 | 103 |

Table 4. One stage clotting activity of peptides A1/3, A1/3-Rd and A1/3-Rd-srmb (sequences see table 2). IZ, buffer control.

Fig. 20 demonstrates the unchanged chromogenic activity of peptide A1/3-Rd. Peptides at a final concentration of 12$\mu$M or the buffer control (IZ) were incubated in the presence of 2.3nM human FIXa (+). The chromogenic activity of peptide A1/3 and A1/3-Rd was found to be virtually unchanged and gave almost identical results in the chromogenic assay. The scrambled version of peptide A1/3, A1/5 as well as the buffer gave no significant FXa generation.

In the next series of experiments we set out to determine the individual role of any amino acid of the peptide core sequence by substituting each residue for the amino acid Alanine (Table 5).

| Peptide | Sequence | Amino acid # | MW (D) | pI | Remark |
|---|---|---|---|---|---|
| A1/3 | RPRPEGGGYYVNWVFDRRR (SEQ.ID.No. 28) | (18aa) | 2407 | 9.9 | Basic pI, soluble, |
| A1/3-13 | RPRP**A**GGGYYVNWVFDRRR (SEQ.ID.No. 29) | (18aa) | 2349 | 10.4 | $E_{13}$-A |
| A1/3-1 | RPRP**A**GGGYYVNWVFDRRR (SEQ.ID.No. 30) | (18aa) | 2421 | 9.9 | $G_1$-A |
| A1/3-2 | RPRPG**A**GGYYVNWVFDRRR (SEQ.ID.No. 31) | (18aa) | 2421 | 9.9 | $G_2$-A |
| A1/3-3 | RPRPGG**A**YYVNWVFDRRR (SEQ.ID.No. 32) | (18aa) | 2421 | 9.9 | $G_3$-A |
| A1/3-4 | RPRPGGG**A**YVNWVFDRRR (SEQ.ID.No. 33) | (18aa) | 2315 | 9.9 | $Y_4$-A |
| A1/3-5 | RPRPGGGY**A**VNWVFDRRR (SEQ.ID.No. 34) | (18aa) | 2315 | 9.9 | $Y_5$-A |
| A1/3-6 | RPRPGGGYY**A**NWVFDRRR (SEQ.ID.No. 35) | (18aa) | 2379 | 9.9 | $V_6$-A |
| A1/3-7 | RPRPGGGYYV**A**WVFDRRR (SEQ.ID.No. 36) | (18aa) | 2364 | 9.9 | $N_7$-A |
| A1/3-8 | RPRPGGGYYVN**A**VFDRRR (SEQ.ID.No. 37) | (18aa) | 2292 | 9.9 | $W_8$-A |
| A1/3-9 | RPRPGGGYYVNW**A**FDRRR (SEQ.ID.No. 38) | (18aa) | 2315 | 9.9 | $V_9$ -A |
| A1/3-10 | RPRPGGGYYVNWV**A**DRRR (SEQ.ID.No. 39) | (18aa) | 2331 | 9.9 | $F_{10}$-A |
| A1/3-11 | RPRPGGGYYVNWVF**A**RRR (SEQ.ID.No. 33) | (18aa) | 2363 | 10.5 | $D_{11}$-A |
| A1/3-12srmb | RPRYVYNGWGYFEG**A**RRR (SEQ.ID.No. 31) | (18aa) | 2363 | 10.4 | Scrambled version |

Table 5. Listed are the peptides designed to elucidate

the role of any single amino acid within the peptide core sequence ($E_1G_2G_3G_4Y_5Y_6V-N_9W_{10}Y_{11}F_{12}D_{13}$). The lower case numbers describe the position of the amino acid within the peptide. Alanine, an uncharged small amino acid, was substituted for each amino acid (''Alanine scan''). Also listed are the lengths of the peptides (amino acids #), the calculated molecular weights (MW, in Dalton (D) and the statistical isoelectric points (pI).

Each of the peptides was dissolved individually in imidazole buffer (50mM imidazole, 100mM NaCl, pH7.2) and subsequently diluted in clotting buffer (50mM imidazole, 100mM NaCl, 1% human albumin, pH7.4) to the desired final concentration. The peptides were analyzed for their chromogenic activity as well as for their potential to reduce the clotting time in a FVIII deficient plasma. The one-stage clotting assay was essentially done as described (see example 6). Clotting times (time from starting the reaction to the ''clot''-formation were compared either against a buffer control or a control peptide (scrambled version).

Some of the results of the ''Alanine scan'' are given for the peptides A1/3-2 and A1/3-3. The change of $G_3$-$A_3$ as exemplified in the peptide A1/3-2 yields high chromogenic activity and a strong reduction of the one-stage clotting time (34 seconds at a concentration of 12.5$\mu$M) in the presence of 2.2nM human FIXa. Peptide A1/3-3 ($G_4$-$A_4$) exhibits an optimum of chromogenic activity around a final concentration of 12$\mu$M with decreased activity at either higher or lower concentrations. The peptide is somewhat inhibitory in a one-stage clotting assay at higher concentrations (12.5$\mu$M) in the absence of FIXa but becomes strongly active in the presence of 2.2nM FIXa (31 seconds, 12.5$\mu$M).

In the next series of experiments we set out to determine the individual role of any amino acid of the peptide core sequence by substituting each core residue

for the amino acid glutamic acid (E) (see Table 6).

| Peptide | Sequence | Amino-Acids | MW (D) | pI | Remark |
|---|---|---|---|---|---|
| A1 3 | RRREGGGYYVNWYFDRRR | (18aa) | 2407 | 9.9 | Basic pI, soluble, |
| A1 3-22 | RRREEGGYYVNWYFDRRR (SEQ.ID.No. 32) | (18aa) | 2479 | 9.5 | $G_2$-$E_2$ |
| A1 3-23 | RRREGEGYYVNWYFDRRR (SEQ.ID.No. 33) | (18aa) | 2479 | 9.5 | $G_3$-$E_3$ |
| A1 3-24 | RRREGGEYYVNWYFDRRR (SEQ.ID No. 34) | (18aa) | 2479 | 9.5 | $G_4$-$E_4$ |
| A1 3-26 | RRREGGGEYVNWYFDRRR (SEQ.ID No. 35) | (18aa) | 2373 | 9.4 | $Y_6$-$E_6$ |
| A1 3-27 | RRREGGGYEVNWYFDRRR (SEQ.ID.No. 36) | (18aa) | 2373 | 9.4 | $Y_6$-$E_6$ |
| A1 3-28 | RRREGGGYYENWYFDRRR (SEQ.ID No. 37) | (18aa) | 2437 | 9.5 | $V_7$-$E_7$ |
| A1 3-29 | RRREGGGYYVEWYFDRRR (SEQ.ID.No. 38) | (18aa) | 2422 | 9.5 | $N_8$-$E_8$ |
| A1 3-30 | RRREGGGYYVNEYFDRRR (SEQ.ID No. 39) | (18aa) | 2350 | 9.5 | $W_9$-$E_9$ |
| A1 3-31 | RRREGGGYYVNWEFDRRR (SEQ.ID.No. 40) | (18aa) | 2373 | 9.4 | $Y_{10}$-$E_{10}$ |
| A1 3-32 | RRREGGGYYVNWYEDRRR (SEQ.ID No. 41) | (18aa) | 2369 | 9.5 | $F_{11}$-$E_{11}$ |
| A1 3-33 | RRREGGGYYVNWYFERRR (SEQ.ID No. 42) | (18aa) | 2421 | 9.9 | $D_{12}$-$E_{12}$ |
| A1/3-34srmb | RRRGEYGEYWNGDFYRRR (SEQ.ID No. 43) | (18aa) | 2437 | 9.5 | Scrambled version |

Table 6. Listed are the peptides designed to elucidate the role of any single amino acid within the peptide core sequence ($E_1G_2G_3G_4Y_5Y_6V_7N_8W_9Y_{10}F_{11}D_{12}$). The lower case numbers describe the position of the amino acid within the peptide. Glutamic acid, a negatively charged large amino acid, was substituted for each amino acid of the core sequence (''Glutamic acid scan''). Also listed are the lengths of the peptide (amino acids #), the calculated molecular weights (MW, in Dalton (D) and the statistical isoelectric points (pI).

Each of the peptides was solved individually in imodazole buffer (50mM imidazole, 100mM NaCl, pH7.2) and subsequently diluted in clotting buffer (50mM imidazole, 100mM NaCl, 1% human albumin, pH7.4) to the desired

final concentration. The peptides derived from the ''Glutamic acid scan'' series were analyzed for their chromogenic FVIII-like activity as well as for their potential to reduce the clotting time in a FVIII deficient plasma. The one-stage clotting assay was essentially done as described (see example 6).

The peptide A1/3-24 showed some interesting properties. The molecule exhibited high chromogenic FVIII-like activity at concentrations between 6.5μM-12μM but lost activity at higher concentrations (up to 24μM). The peptide had no procoagulant activity in the absence of human FIXa but was strongly active in the presence of 2.2nM hFIXa.

In a second series of experiments we set out to improve the procoagulant activity of the antibody 198/B1 CDR3H derived peptide sequence B1. In a first step we improved the solubility of the original peptide sequence (B1; EGGGFTVNWYFDV) by removing the C-terminal Val residue and adding several charged residues at the N- as well as the C-terminal end of the peptide. The resulting peptides B1/4, B1/6 (acidic pI), B1/7 (basic pI) and their scrambled versions B1/5, B1/7scr3 are readily soluble in a variety of buffer systems at physiological pH.

| Peptide | Sequence | Amino-acids | MW (D) | pI | Remark |
|---|---|---|---|---|---|
| B1 | EGGGFTVNWYFDV (SEQ.ID.No. 44) | (13aa) | 1491 | 6.0 | Decreased solubility |
| B1_4 | REGGGFTVNWYFDR (SEQ.ID.No. 45) | (14aa) | 1704 | 7.9 | Soluble, |
| B1_5 | FGVGYRGETRNFDW (SEQ.ID.No. 46) | (14aa) | 1704 | 8.0 | Scrambled version, soluble |
| B1_6 | EEEEGGGFTVNWYFDEEE (SEQ.ID.No. 47) | (18aa) | 2166 | 5.0 | Acidic pI soluble |
| B1_7 | RRREGGGFTVNWYFDRRR (SEQ.ID.No. 48) | (18aa) | 2329 | 9.9 | Basic pI soluble |
| B1_7scr3 | RRRFGVGYGETNFDWRRR (SEQ.ID.No. 49) | (18aa) | 2329 | 9.9 | Basic pI, soluble, scrambled version |

Table 7 is a list of a series of antibody 198/B1 derived

peptides. Listed are the length of the peptide (aa, amino acids #), the calculated molecular weight (MW, in Dalton (D) and the statistical isoelectric point (pI).

Peptides B1/4 and B1/5 were soluble in 50mM Tris, 100mM NaCl, pH=6.5. Both peptides were analyzed in a chromogenic FVIII assay. Peptide B1/4 but not the scrambled version B1/5 was found to have some chromogenic activity (data not shown).

Subsequently peptides B1/6, B1/7 and B1/7scr3 were analyzed. Each of the peptides was solved individually in 50mM imidazole, 100mM NaCl, pH7.2 and subsequently diluted either in clotting buffer (50mM imidazole, 100mM NaCl, 1% human albumin, pH7.4) or in imidazole buffer to the desired final concentration. The peptides were analyzed for their chromogenic activity as well as for their potential to reduce the clotting time in a FVIII deficient plasma (table 8 & 9). The one stage clotting assay was essentially done as described (see example 6). Clotting times (time from starting the reaction to the ''clot''-formation were compared either against a buffer control or a control peptide (scrambled version).

The FIXa activating activity (FVIII cofactor-like activity) from peptide B1/7 was first measured in the chromogenic assay described above.

As shown in Fig. 21, the addition of 2.4μM peptide B1/7 to the reaction mixture led to a well measurable generation of FXa. In contrast, the addition of 35μM Pefabloc Xa, a specific inhibitor of FXa protease activity, resulted in a significant reduction of the chromogenic substrate cleavage reaction (Fig. 22) thereby proving that there was indeed a peptide-FIXa mediated FXa generation. If there was no addition of FIXa and FX to the reaction mixture, no FXa was synthesized (Fig. 22). Peptide B1/6 and the control peptides B1/5 and B1/7scr3 exhibited no activity (data not shown).

Fig. 21 demonstrates the chromogenic activity of

peptide B1/7. The peptide at a final concentration of 2.4μM or the buffer control (IZ) were incubated in the presence of 2.3nM human FIXa.

In Fig. 22 peptide B1/7 at a final concentration of 2.4μM or the buffer control (IZ) were incubated in the presence of 2.3nM human FIXa (as indicated either as''+2.3nM hFIXa'' or ''+''). The chromogenic activity of peptide B1/7 was found to be dependent on the presence of FIXa and FX since no reaction is detectable when FIXa and FX are left out of the reaction (w/o FIXa/FX). To prove that the peptide B1/7 mediates indeed FXa generation, the FXa specific protease inhibitor Pefabloc Xa was added to the reaction mix (35μM Pefabloc Xa).
In a second set of experiments, the procoagulant effect of peptides B1/6, B1/7 and B1/7scr3 were tested in a aPTT based one-step coagulation assay. The experiments were done essentially as described in Example 6. The results are shown in tables 8 and 9.

| Peptide | 12.5μM (-) | 1.25μM (-) | 0.125μM (-) | 12.5nM (-) | Buffer (-) | remarks |
|---|---|---|---|---|---|---|
| B1/6 | 115 | 110 | 111 | 111 | 110 | |
| B1/7 | 157 | 112 | 109 | 110 | 110 | |
| B1/7scr3 | 115 | 105 | 106 | 105 | 107 | |

Table 8: FVIII deficient plasma was incubated either with peptides B1/6, B1/7scr3 or B1/7 in the absence of activated human FIX. As a negative control, plain buffer was added to the deficient plasma. The clotting times for the various combinations are given. Under these conditions, peptide B1/7 at its highest concentration (12.5μM) becomes inhibitory to the coagulation process as indicated by the extended clotting time of 157 seconds.

| Peptide | 12.5μM (+) | 1.25μM + | 0.125μM + | 12.5nM + | Buffer + | remarks |
|---|---|---|---|---|---|---|
| B1/6 | 103 | 100 | 101 | 100 | 100 | |
| B1/7 | 83 | 92 | 99 | 99 | 100 | |
| B1/7scr3 | 102 | 94 | 94 | 94 | 94 | |

Table 9: FVIII deficient plasma was incubated either with peptides B1/6, B1/7scr3 or B1/7 in the presence of activated human FIX. As a negative control, plain buffer was added to the deficient plasma. The clotting times for the various combinations are given. In the presence of FIXa, peptide B1/7 becomes procoagulant as indicated by the reduced clotting time (83 seconds compared to 102 seconds for the scrambled peptide and 100 seconds for the buffer control).

**Example 12: Procoagulant activity of peptide derivatives obtained from CDR3 regions of anti-FIX/FIXa-antibodies in FVIII inhibitor plasma**

To assay for the procoagulant activity of peptide A1/3 in FVIII inhibitor plasma the following experiment was carried out. We performed a standard aPTT based one stage clotting assay, but instead of FVIII deficient plasma we employed FVIII inhibitor plasma. The inhibitory potency of the plasma was 8.1 Bethesda Units per ml.

| | | w/c FIXa | w/o FIXa | | | FIXa | FIXa | |
|---|---|---|---|---|---|---|---|---|
| | Peptide conc. | sec | sec | **Average sec** | | sec | sec | **average sec** |
| IZ | 0 | 104.8 | 103.6 | **104** | | 94.2 | 94.1 | **94** |
| A1/3 | 12.5μM | 85.8 | 85.3 | **86** | | 61 | 60.2 | **61** |
| | 10μM | 88.4 | 87.9 | **88** | | 61.3 | 61.8 | **62** |
| | 7.5μM | 93.7 | 92.7 | **93** | | 68.8 | 70.9 | **70** |
| | 5μM | 101.5 | 101.1 | **101** | | 81 | 82 | **82** |
| | 2.5μM | 106.1 | 105.3 | **106** | | 90.2 | 90.5 | **90** |
| | 1.25μM | 104.5 | 104.3 | **104** | | 91.3 | 91.4 | **91** |

Table 10: Various amounts of peptide A1/3 (12.5μM-1.25μM) were added to FVIII inhibitor plasma (either in

the presence (FIXa) of 2.2nM FIXa or in the absence (w/o FIXa). As a negative control, plain buffer was added to the plasma (IZ). Experiments were done in duplicate and the average (aver.) was calculated. The clotting times (in seconds) for the various combinations are given. It is easily appreciable that the peptide A1/3 reduces (in a dose dependent manner) the clotting time of FVIII inhibitor plasma in the presence of FIXa but, although albeit to a much lesser extent, also in the absence of FIXa.

**Example 13: Conversion of the 196/C4 IgM into IgG1**

Since some IgM antibodies demonstrate high FVIII-like activity in chromogenic assays, attempts were made to convert such IgM antibodies into IgG antibodies (though antibody derivatives such as Fab, F(ab)2, scFv, etc. could also be produced). Described in detail below is the rescue of the IgM variable region genes. Expression vector pBax-IgG1 (Fig. 23) was first constructed from vectors pSI (Promega) and pEF/Bsd (Invitrogen) through multiple cloning steps. B-lymphocytes of a donor are purified from blood and mature mRNA purified from these cells using the "micro-mRNA purification-kit" (Pharmacia). The cDNA of a human kappa chain and a human gamma 1 chain are prepared employing the "you-primefirst-strand-cDNA-"kit'' (Pharmacia) using specific primers.

The coding sequence of a human kappa light chain constant domain is amplified from the cDNA by PCR using specific primers.

The gene of a human gamma 1 chain constant region (CH1-hinge-CH2-CH3) is amplified from the cDNA by PCR using specific primers.

The PCR product of the light chain constant domain is digested with XbaI and NheI and inserted into digested pSI. The resultant vector is cleaved with EcoRI and XbaI and annealed oligonucleotides are inserted, resulting in vector pSI-Ckappa. The annealed

oligonucleotides provide for the leader and the SacI-XbaI sites for insertion of the kappa chain variable region. The PCR product of the human gamma 1 chain constant region is digested with SpeI and BamHI and inserted into digested pSI. The resultant vector is cleaved with SpeI and NotI and annealed oligonucleotides are inserted resulting in vector pSI-Cgamma. The annealed oligonucleotides provide for the leader and the XhoI-BstEI sites for insertion of the heavy chain variable region. Vector pEF/Bsd is digested NheI and SfiI, blunt ended by Klenow treatment and the whole expression cassette of pSI-Ckappa, excised with BglII and BamH1, is inserted (after Klenow treatment). The resultant vector is digested with EcoRI and HindIII and treated with Klenow. The whole expression cassette of pSI-Cgamma is excised with BglII and BamH1 and is inserted (after Klenow treatment). The resultant vector is named pBax-IgG1.

The light chain variable region can be inserted in between the SacI-XbaI sites, yielding the complete coding-sequence of a kappa light chain. The heavy chain variable region can be cloned in between the XhoI-BstEI sites, resulting in a complete IgG1 heavy chain gene. Both open reading frames are expressed under the control of the SV40-promoter and harbour the coding sequence of a signal peptide at the 5' end of the genes for secretion of the heavy and light chains into the endoplasmatic reticulum. Transfection into COS cells allows the expression of an IgG1 with the same binding properties as the parental IgM.

Construction of the plasmid pBax-196/C4 is further accomplished by amplifying the VH of the 196/C4 scFv (subcloned as described in Experiment 10) by PCR using specific primers. The PCR product is digested with XhoI and BstEII and inserted into XhoI and BstEII digested pBax IgG1. The VL of the 196/C4 scFv is amplified by PCR using specific primers. The PCR product is digested with

SacI and XbaI and inserted into SacI and XbaI-digested pBax IgG1-VH. The resultant vector (pBax-196/C4) is transfected into COS cells by electroporation, and hybrid IgG1 molecules (murine variable region and human constant region) with the same specificity as the parental IgM is expressed.

**Example 14: Activation of FIXa amydolytic activity by anti-FIXa antibodies:**

Briefly, 20µl factor IXa (containing 200mU FIXa (Stago)) were incubated at 37°C, with 200µl of reaction buffer (50mM TrisHCl pH7.4, 100mM NaCl, 5mM $CaCl_2$ and 40% Ethyleneglycol), 25µl of FIXa substrate ($CH_3SO_2$-D-CHG-Gly-Arg-pNA,AcOH, 10µM/ml, Pentapharm LTD) in the absence or presence of various amounts of anti-FIX antibodies 198/B1 (IgG isotype) or 196/AF1 (IgM isotype). Specific cleavage of FIXa substrate was monitored at 405nm in an ELISA reader.

The presence of the anti-FIX antibodies enhanced the amydolytic activity of FIXa at least 2 fold. Fig. 24 shows the increase of the amidolytic activity of FIXa in the presence of antibody 198/B1 (Fig. 24A) and antibody 198/AF1 (Fig. 24B).

**Example 15: FVIII-like activity exhibited by Fab fragments derived from anti- FIX/FIXa-antibodies.**

Fab fragments of anti-FIX/FIXa antibodies were prepared and purified according to standard protocols. Briefly, 1ml antibody 198/A1(4mg/ml in 50mM imidazole, 100mM NaCl, pH7.4) was incubated overnight with 87µl fragmentation buffer (1M Na Acetate, 10mM EDTA 67.5mg/ml L-cysteine) and 0.25mg papain (immobilized on agarose beads), at 37°C. The preparation was filtered to remove the papain. L-histidine was added (final concentration 50mM) and afterwards the pH was adjusted to 7.0. Finally, solid NaCl is added to give a final concentration of 1M.

Subsequently, the 198/A1 Fab fragment was purified

by binding to protein L: We used ImmunoPure Immobilized PROTEIN L Plus (Pierce) in a PHARMACIA XK 16/20 Column (gel-volume: 2ml) Buffers for chromatography were: 1) equilibration-buffer : 50mM L-histidine pH 7.0; 1M NaCl; 0,1% (w/v) $NaN_3$; 2) wash-buffer: 50mM L-Histidine pH 7.0; 0.1% (w/v) $NaN_3$; 3)elution-buffer: 100 mM glycine pH 2.5; 0.1% (w/v) $NaN_3$; and 4) neutralization buffer: 2M Tris/Cl pH 8,0;

Chromatography was essentially done by following steps 1 to 7 described in table 11. In order to neutralize the low pH of the elution buffer ''Fraction-tubes'' were pre-loaded with 0.2 ml 2M Tris pH 8.0.

| | STEP | BUFFER | Flow rate | Vol. | CV | Fractions |
|---|---|---|---|---|---|---|
| 1. | column-wash | elution-buffer | 2.0 ml/min | 10 ml | 5 | waste |
| 2 | equilibration | equi-buffer | 2.0 ml/min | 10 ml | 5 | waste |
| 3 | sample-load | sample | 1.0 ml/min | x ml | x | flow-through |
| 4 | wash 1 | equi-buffer | 1.0 ml/min | 20 ml | 10 | flow-through |
| 5. | wash 2 | wash-buffer | 1.0 ml/min | 10 ml | 5 | flow-through |
| 6. | elution | elution-buffer | 1.0 ml/min | 15 ml | 7.5 | 1.0 ml fractions- |
| 7. | neutralization | wash-buffer | 2.0 ml/min | 10 ml | 5 | waste |

Table 11

The final 198/A1 Fab preparation was dialyzed against 50mM imidazole, 100mM NaCl, pH7.4 and analyzed in a chromogenic FVIII assay as described above (Fig. 25). Compared to an intact antibody, the 198/A1 Fab fragment has somewhat less activity; however, the Fab fragment still gives rise to FIX dependent FXa generation.

Fig. 25 demonstrates the chromogenic FVIII-like activity of the antibody 198/A1 Fab fragment in the presence of 2.3nM human FIXa. As a positive control we used the intact antibody 198/A1 as well as 7.5pM FVIII. Buffer control (IZ) instead of 198/A1 Fab fragment or FVIII was used as a negative control.

**Example 16: FVIII-like activity exhibited by fusion**

**proteins between scFv fragments of anti-FIX/FIXa antibodies and E. coli alkaline phosphatase.**

The single chain Fv fragment (see example 10) of antibody 198/B1 (subclone AB2) was fused to the N-terminus of E. coli alkaline phosphatase employing the pDAP2 vector system (Kerschbaumer et al., 1996). Two identical clones were isolated and designated pDAP2-198AB2#1 and pDAP2-198AB2#100 (Fig. 26). The resulting fusion proteins were expressed in E. coli, purified by metal affinity chromatography (Kerschbaumer et al., 1997) and analysed in a standard chromogenic assay (Fig. 27).

Fig. 27 demonstrates the chromogenic FVIII-like activity of two antibody 198/B1 (subclone AB2) scFv fragment-alkaline phosphatase fusion proteins (198AB2#1 and 198AB2#100) in the presence of 2.3nM human FIXa. As a positive control we used 7.5pM FVIII.

**Example 17: FVIII-like activity exhibited by a bivalent miniantibody.**

In order to obtain a bivalent miniantibody, the scFv fragment of antibody 198/B1 (subclone AB2) was fused to a amphipatic helical structure employing the pZip1 vector system (Kerschbaumer et al. (*Analytical Biochemistry* 249, 219-227, 1997). Briefly, the gene of the 198/B1 scFv fragment was isolated from the plasmid pDAP-198AB2#100 (example 16) by digestion with SfiI and NotI. The DNA fragment was gel purified and inserted in the SfiI/NotI digested vector pZip1. The resulting plasmid was sequenced and designated pZip-198AB2#102 (Fig.28). In parallel, we constructed a miniantibody version from an irrelevant monoclonal antibody termed #8860. In a first step, the single chain Fv fragment of antibody #8860 was assembled in the vector pDAP2. The cloning was done essentially as described in example 10. The construct was named pDAP2-8860scFv#11 (Fig. 29).

Subcloning of the scFv fragment contained within pDAP2-8860scFv#11 into plasmid pZip1 (see above) yielded the miniantibody construct p8860-Zip#1.2 (Fig. 30). Since antibody #8860 does not react with FIX/FIXa (as judged by Western Blot and ELISA analysis) it represents an appropriate negative control. Subsequently, the miniantibody proteins were expressed in E. coli and purified from bacterial supernatants by binding to Protein L according to the following protocol:

For affinity chromatography we used ImmunoPure Immobilized PROTEIN L Plus (Pierce) in a PHARMACIA XK 16/20 Columns having a gel-volume of 4ml

Buffers employed were: 1) equilibration-buffer : 50mM L-Histidine pH 7.0, 1M NaCl, 0.1% (w/v) $NaN_3$, wash-buffer: 50mM L-histidine pH 7.0, 0.1% (w/v) $NaN_3$, elution-buffer: 100 mM glycine pH 2.5, 0.1% (w/v) $NaN_3$, and neutralization buffer: 2M Tris/Cl pH 8.0

Samples were prepared as follows: The bacterial culture supernatant was obtained by centrifugation of the bacterial expression culture (11,000 x g, 4°C, 10 minutes). 470 g of ammonium-sulphate was added to 1 liter of supernatant and the solution stirred on ice for 1 hour to precipitate the protein. The precipitate was pelleted at 14,000 x g for 35 minutes at 2°C and re-dissolved in 100 ml 20mM Tris pH 7.0. Subsequently the concentrate was dialyzed against 20mM Tris pH 7.0, L-histidine was added to a final concentration of 50mM and the pH was adjusted to 7.0. Finally, solid NaCl was added to give a final concentrations of 1M. Before loading on the column, a sample was first centrifuged at 16,000 x g for 15 min at room temperature and then filtered through a 0.45$\mu$m sterile filter.

Chromatography was essentially done by following steps 1 to 7 described in table 12. In order to neutralize the low pH of the elution buffer ''Fraction-tubes'' were pre-loaded with 0.2 ml 2M Tris pH 8.0.

| | STEP | BUFFER | Flow rate | Vol. | CV | Fractions |
|---|---|---|---|---|---|---|
| 1. | column-wash | elution-buffer | 2.0 ml min | 20 ml | 5 | waste |
| 2. | equilibration | equi-buffer | 2.0 ml min | 20 ml | 5 | waste |
| 3. | sample-load | sample | 1.0 ml min | x ml | x | flow-through |
| 4. | wash 1 | equi-buffer | 1.0 ml min | 40 ml | 10 | flow-through |
| 5. | wash 2 | wash-buffer | 1.0 ml min | 20 ml | 5 | flow-through |
| 6. | elution | elution-buffer | 1.0 ml min | 30 ml | 7.5 | 1.0 ml fractions- |
| 7. | neutralization | wash-buffer | 2.0 ml min | 20 ml | 5 | waste |

Table 12. The final 198/B1 (subclone AB2) miniantibody preparation (designated 198AB-Zip#102) and the negative control 8860-Zip#1.2 were dialyzed against 50mM imidazole, 100mM NaCl, pH7.4 and analyzed in a chromogenic FVIII assay as described above (Fig. 31).

As can be seen in Fig. 31, the miniantibody construct 198AB-Zip#102 gives rise to substantial FXa generation (compare to FVIII) whereas the negative control miniantibody 8860-Zip#1.2 does not.

Fig. 31 demonstrates the chromogenic FVIII-like activity of the 198/B1 (subclone AB2) miniantibody 198AB-Zip#102 in the presence of 2.3nM human FIXa. As a positive control we used 4.8pM FVIII whereas an unrelated miniantibody (8860-Zip#1.2) and plain reaction buffer (IZ) served as negative controls.

**Example 18: FVIII-like activity exhibited by anti-FIXa/FIX antibody scFv fragments**

The single chain Fv fragment of antibody 198/B1 (subclone AB2) as well as the scFv fragment of antibody #8860 were expressed employing the pMycHis6 vector system. Vector pMycHis6 (Fig. 32 & 33) was constructed by cleaving vector pCOCK (Engelhardt et al., 1994, Biotechniques, 17:44-46) with NotI and EcoRI and insertion of the following oligonucleotides: mychis6-co: 5'ggccgcagaacaaaaactcatctcagaagaggatct gaatggggcggcacatcaccatcaccatcactaataag 3' (SEQ.ID.NO. 79) and mycchis-ic:5'aattcttattagtgatggtgatggtgatgtgccgccccattcagatcctct tctgagatgagtttttgttctgc 3' (SEQ.ID.NO. 80)

Fig. 32 shows a schematic representation of the plasmid pMycHis6. The c-myc-tag sequence is used to detect the scFv fragment in an ELISA or a Western Blot analysis (Evan et al., Mol.Cell.Biol., 1985, 5(12), pp. 3610-6). The His6-tag sequence was included to facilitate the purification of scFv fragments by metal ion chromatography (Hochuli et al., 1988. Biotechnology, 6:1321-1325). The plasmid contains the lacZ gene promoter (PlacZ) the PelB-leader sequence (see legend Fig. 26) an E. coli origin of replication (colE1ori) and a M13 phage origin of replication (M13ori). To allow for specific selection, the plasmid also carries the gene for the enzyme ß-lactamase (AmpR) mediating resistance against the antibiotic ampicillin.

The gene of the 198/B1 (clone AB2)-scFv was rescued from plasmid pDAP2-198AB2#100 (example 16) by digestion with SfiI and NotI and inserted into SfiI/NotI cleaved pMycHis6. The resultant plasmid was designated pMycHis-198AB2#102. Fig. 34 shows the nucleotide and amino acid sequence of 198AB2 scFv (linked to the c-myc-tag and the His6- tag):the resulting ORF of the expression vector is named pMycHis6-198AB2#102. Vector pMycHis6 was constructed by cleaving vector pCOCK (Engelhardt O. et al, BioTechniques 17, 44-46, 1994) NotI - EcoRI and inserting the following annealed oligonucleotides: (5'-GGCCGCAGAACAAAAACTCATCTCAGAAGAGGATCTGAATGGG GCGGCACATCACCATCACCATCACTAATAAG - 3' (SEQ.ID.No. 103) and 5'- TTATTAGTGATGGTGATGGT GATGTGCCGCCCCATTCAGATCCTCTTCTGAGATGAGTTTTTGTTCTGC-3'(SEQ.ID.NO. 104)). The resultant vector, named pMycHis6, was cleaved SfiI - NotI and the gene of scFv 198AB2 was swapped into this vector from vector pDAP2-198AB2#100.

In analogy to the 198AB2 construct, the #8860 scFv fragment was cloned from a plasmid designated pDAP2-8860scFv clone 11. The pure scFv protein of #8860 was designated 8860-M/H#4c (plasmid p8860-M/H#4c, Fig. 35).

The scFv proteins were expressed in E. coli and affinity purified from bacterial supernatants on Protein L columns (see example 17). The final MycHis-198AB2#102 and 8860-M/H#4c preparations were dialyzed against 50mM imidazole, 100mM NaCl, pH7.4 and analyzed in a chromogenic FVIII assay as described above (Fig. 36).

As can be seen in Fig. 36, the scFv construct MycHis-198AB2#102 gave rise to a substantial FXa generation whereas the negative controls 8860-M/H#4c and plain reaction buffer (IZ) did not.

Fig. 36 demonstrates the chromogenic FVIII-like activity of the 198/B1 (subclone AB2) scFv fragment (MycHis-198AB2#102) in the presence of 2.3nM human FIXa. As a positive control we used 4.8pM FVIII whereas a unrelated scFv (8860-M/H#4c) and plain reaction buffer (IZ) served as negative controls.